Studies on ecology of soft-bottom meiobenthic community from Sundarban estuarine system, West Bengal, India

MOUMITA GHOSH

Ph.D. Registration No. : R-14RS18210018 Dated 5th May, 2016

Enrollment No. : SC/DOC/13-14/15 Dated 6th May, 2014

Supervisor: Dr. Sumit Mandal

Marine Ecology Laboratory

Department of Life Sciences

Presidency University

Kolkata – 700073, India

SYNOPSIS [5OOO WORDS]

NAME : MOUMITA GHOSH

SUPERVISOR : DR. SUMIT MANDAL, Assistant Professor
Department of Life Sciences, Presidency University
Kolkata - 700073, West Bengal, India
sumit.dbs@presiuniv.ac.in

TITLE OF THE THESIS : Studies on ecology of soft-bottom meiobenthic community from Sundarban estuarine system, West Bengal, India

Ph.D. REGISTRATION NO.: R-14RS18210018 Dated 5th May, 2016

ENROLLMENT NO. : SC/DOC/13-14/15 Dated 6th May, 2014

PLACE OF WORK : Marine Ecology Laboratory, Presidency University,
Kolkata - 700073

RESIDENTIAL ADDRESS : 34, Feeder Road, Aaheli Apartment, 3rd Floor, R. No. 5,
Kolkata - 700056

CORRESPONDING ADDRESS: 34, Feeder Road, Aaheli Apartment, 3rd Floor, R. No. 5,
Kolkata - 700056

E-MAIL : gmoumita02@yahoo.com, moumita.rs@presiuniv.ac.in

PHONE NUMBER : 9836020589

SIGNATURE OF RESEARCH SCHOLAR SIGNATURE OF SUPERFVISOR

CONTENTS

	PAGE
1. Abstract	1
2. Introduction	2
3. Objectives of the study	3
4. Methodology	3
4.1 Objective 1 & 2	3
4.1.1 Study area	3
4.1.2 Sample collection	3
4.1.3 Meiofaunal analyses	4
4.1.4 Nematofaunal analyses	4
4.1.5 Environmental parameter analyses	4
4.2 Objective 3	5
4.2.1 Study area	5
4.2.2 Sample collection	5
4.2.3 Meiofaunal & nematofaunal analyses	5
4.1.4 Environmental parameter analyses	5
4.3 Objective 4	6
4.3.1 Sample collection	6
4.3.2 Experimental design	6
4.3.3 Faunal analyses	7
5. Results	8
5.1 Objective 1 & 2	8
5.2 Objective 3	10
5.3 Objective 4	12
6. Conclusion	13
7. References	14

Summary of Work

Title: Studies on ecology of soft-bottom meiobenthic community from Sundarban estuarine system, West Bengal, India.

1. Abstract

Structure of meiobenthic assemblage was assessed for the first time from world's largest mangrove ecosystem, Sundarbans, focusing on free living nematode species composition (~ 90% of the total population). The present research revealed the deleterious effect of excessive monsoonal rain on meiobenthos as well as free-living nematode assemblages. Abundance of meiobenthos declined from early monsoon to later period of monsoon due to massive riverine runoff followed by cloudburst phenomenon that completely flushed the estuary. Significant temporal and spatial heterogeneity in the abundance of meiofauna and nematode species composition was also described in relation with environmental variables. Distinct seasonal fluctuation of meiofauna was prominent due to seasonal changes in sedimentary environment. Nematodes dominated the meiofaunal assemblages and ranking harpacticoid copepod in the second position. Altogether, 79 species of free-living nematode had been identified for the first time and nematode assemblage was dominated by *Sabatieria preadatrix*, *Sphaerolaimus bulticus*, *Desmodora communis*, *Dorylaimopsis punctata* and *Daptonema hirsutum*. Biological trait approach of nematode assemblages was applied to investigate the ecological functioning based on morphological and ecological characteristics, which added relevant information regarding relationships between species diversity and the abiotic environment. Furthermore, present study conducted a pioneering survey regarding vertical stratification of meiofaunal assemblages in different mangrove vegetation with nematofaunal species level information. This study clearly depicted that more than 90% of meiofaunal organisms was concentrated within upper 3-4 cm of sediment, though they were present up to 15 cm of depth. Furthermore, combined effect of climate change mediated elevated temperature and petroleum pollution on meiobenthic organisms were also investigated through a mesocosm experiment. The present research highlighted harmful effects of these stressors on meiobenthic species composition and abundance. Present observation would be a maiden footstep to understand the resilience of meiobenthic organisms to predicted climate change scenarios.

2. Introduction

Benthos are organisms living on or near the bottom sediment of any aquatic environment. Based on size benthic domain is classified into 3 major classes: macrobenthos (> 500 μm), meiobenthos (63 to 500 μm) and microbenthos (< 63 μm) (Giere, 2009). Meiobenthic organisms (or meiofauna) are found from intertidal zone to deep sea. In marine ecosystems meiofauna contribute to a great extent in terms of total benthic biomass. They play a pivotal role in biomineralization of detrital matter and enhance the nutrient regeneration for other trophic levels by breaking down detritus (Coull, 1999). Their role in enriching the overlying water with nutrients has also been well established. Meiobenthos act as food for macrobenthos, juvenile demersal fishes and shrimp (Schratzberger and Ingels, 2017). Meiobenthic organisms can be used as proxy to environmental changes due to their small sizes, ubiquitous distribution, higher abundance, fast generation cycles and direct benthic development (Vanaverbeke et al., 2011; Zeppilli et al., 2015).

Among meiobenthic taxa free-living nematodes and harpacticoid copepods constitute more than 90% of the fauna. Other taxa include benthic foraminifera, ostracods, kinorhynchs, turbellaria, gastrotrichs, tardigrades etc. As nematodes are always the dominant and species-rich meiofaunal taxon, we are interested to gather in-depth knowledge of this taxon. Their diversities vary as a function of availability of sediment pore water oxygen, organic matter, sediment texture and other environmental variables (Heip et al., 1985). Owing to such immense importance of meiofauna, especially nematodes, in ecosystem functioning, their studies need to be approached with proper systematic and scientific manner.

From Indian estuaries, meager amount of studies on meiobenthos has been documented giving emphasis on the species level composition and temporal succession. Along the eastern coastal belt of India, majority of the studies were carried out from Tamil Nadu and Andhra coast, however very few fragmented studies are available on meiofauna inhabiting the estuarine phase of Indian Sundarbans (Rao and Mishra, 1983), that too emphasizing only on foraminifera distribution (Dey et al., 2012; Sen et al., 2016). Hence, formulation of a systematic and reliable database for estuarine meiobenthic fauna, focusing on nematode species composition, from fragile and ecologically important Sundarban estuarine system (SES) is of crucial importance.

3. Objectives of the study

I. Documentation of spatial and temporal variations in meiobenthic distribution of Sundarban estuarine system.
II. Understanding environmental factors influencing distribution pattern of meiobenthic assemblages of aforesaid area.
III. Study of vertical distribution of meiofauna in response to physico-chemical variables.
IV. Observation of the potential environmental disturbances including climate change upon meiobenthic animals.

4. Methodology

4.1 Objective 1 & 2:

Documentation of spatial and temporal variations in meiobenthic distribution of Sundarban estuarine system and understanding environmental factors influencing distribution pattern of meiobenthic assemblages of aforesaid area.

4.1.1 Study area

Sundarbans, the largest contiguous deltaic mangrove ecosystems of the world, is situated on the delta created by Ganges, Meghna and Bhramaputra rivers covering coastal belt of India and Bangladesh (Papa et al., 2010). This coastal mangrove ecosystem is interconnected by hundreds of islands and numerous creeks, inlets and canals. For present investigation, we selected two rivers: Matla (one of the major tidal rivers of SES) and Jagaddal, a headwater of river Saptamukhi (Fig 1).

4.1.2 Sample collection:

From inner estuary of Jagaddal, sediment samples were collected before (July) and after (September) the heavy rainfall in August 2013 selecting 15 stations along the salinity gradient. For Matla river, the study was carried out selecting 8 stations during four different seasons (monsoon, winter, spring and summer). Triplicate samples were taken for meiobenthos analyses by a van Veen grab (0.04 m^2) from each study site and from each grab sample two subsamples were collected using a hand corer (5.6 cm internal diameter). One core of subsample was stored immediately in buffered Rose Bengal (0.5 g l^{-1}) formalin at a concentration of 4 % (Danovaro et

al., 2004) and subsequently processed in the laboratory. Another core of subsample was analyzed for environmental parameters analyses.

4.1.3 Meiofaunal analyses:

Sediment subsamples were then washed through a set of sieves (500 and 63 µm) to isolate macro and meiobenthic organisms respectively (Pfannkuche and Thiel, 1988). The sediment retained in 63 µm sieve was then decanted to extract meiofauna following the method of Armenteros et al., (2008). Collected organisms were sorted and enumerated under a zoom stereomicroscope (Nikon SMZ745T). The abundance was expressed in individuals 10 cm^{-2} ± SD.

4.1.4 Nematofaunal analyses:

From each subsample, 100 marine nematode specimens were randomly picked and mounted with the help of anhydrous glycerin (Vincx, 1996) onto glass slides for identification upto species level under a compound microscope containing a camera (Nikon ECLIPSE C*i*) based on standard pictorial keys (Platt and Warwick, 1983, 1988; Warwick et al., 1998) and online identification key: NeMys (Bezerra et al., 2019).

For Biological Trait Analysis (BTA) four traits were selected: three morphological (buccal cavity structure, adult body shape and tail shape) and one ecological (life-history strategy). On the basis of buccal morphology, feeding guild of each nematode species were assigned according to Wieser's (1953) classification: 1A- selective deposit feeders, 1B- non-selective deposit feeders, 2A- epistrate feeders and 2B- carnivorous / omnivorous. Three groups of adult body shape of nematodes were obtained from the literature of Soetaert et al., (2002) - stout, slender and long / thin. Individual nematode was categorized into four tail shape following the classification of Thistle et al., (1995) - short / round, elongated / filiform, conical and clavate. According to Bongers et al., (1991, 1995), each nematode specimen was classified one of the five c-p (colonizer-persister) categories: 1- colonizers (opportunistic species; r-strategists); 2-tolerant to stress; 3- intermediate; 4- highly sensitive to stress and 5- persisters (k-strategists).

4.1.5 Environmental parameter analyses:

Temperature of sediment was measured by mercury thermometer during sample collection. Niskin water sampler (5 L) was used to collect bottom water for analyses of pH, dissolved oxygen (DO) and salinity according to standard protocols of Strickland and Parsons, (1972). Microphytobenthos or chlorophyll *a* (Chl *a*) concentration of sediment was estimated by

the acetone extraction method (Strickland and Parsons, 1972). Organic carbon of sediment was analyzed using chromic acid oxidation method followed by titration with 0.2 N ammonium ferrous sulfate (El Wakeel and Riley, 1957). Sediment granulometry was analyzed following sieve and pipette method (Folk, 1968). Suspended particulate matter (SPM) were determined following literature of Harrison et al., (1997).

4.2 Objective 3:

Study of vertical distribution of meiofauna in response to physico-chemical variables.

4.2.1 Study area

Sediment samples were collected from Bali Island, northern region of Matla river estuary of Sundarbans. Five most imperative mangrove species were selected for the present investigation: *Aegiceras corniculatum*, *Avicennia alba*, *Bruguiera gymnorrhiza*, *Rhizophora mangle* and *Sonneratia caseolaris*.

4.2.2 Sample collection

Mangrove sediments were collected at low tide using a hand operated acrylic corer (internal diameter: 6 cm and length: 20 cm) from five aforesaid mangrove vegetation. From each vegetation, triplicate sediments were taken up to the depth of 15 cm. Each core then was sliced *in situ* into 0 to 1, 1 to 2, 2 to 3, 3 to 4, 4 to 5 and 5 to 15 cm. The sediments were fixed, enumerated and analyzed according to methodology described in section 4.1.

4.2.3 Meiofaunal & nematofaunal analyses

Same as described in section 4.1.

4.2.4 Environmental parameter analyses

During sample collection sediment temperature and sediment pore water dissolved oxygen (DO), salinity & pH were examined by thermometer, DO meter (Thermo Scientific, RDO), refractometer (Atago Japan) and hand operated pH meter (Eco testr pH2) respectively. Sediment texture, organic carbon and Chl *a* analyses were carried out by the same method as mentioned in 4.1.

4.3 Objective 4:

Observation of the potential environmental disturbances including climate change upon meiobenthic animals.

4.3.1 Sample collection

Sediments with natural meiofaunal communities were collected from high intertidal mudflat during low tide. We randomly collected upper 2 cm of the sediments in a large tank (40 x 30 x 40 cm) with a shovel and carefully homogenized them by gentle mixing. Homogenized sediments then carefully washed through 500 μm sieve using filtered sea water to remove macrofauna, shell debris and pebbles. Sieved sediments were then placed in a plastic aquaria (40 x 28 x 20 cm), not exceeding a sediment depth of 5 cm to avoid anoxic condition. A total nine plastic aquaria with sieved sediments were returned to the laboratory. Filtered sea water was carefully added to each aquarium up to 5 cm above sediment surface and left for 48 h for acclimatization prior to the experiments. Light was controlled in a 12/12 h light/dark cycle and seawater aeration of each aquarium was ensured with continuous O_2 bubbling. The experiment ran for 60 days.

Ambient pore water temperature, salinity, dissolved oxygen and pH were recorded at the time of sampling. Additional sediment was collected for organic carbon and granulometric analyses.

4.3.2 Experimental design

A. Temperature treatment

Three large tanks (80 x 50 x 40 cm) were used for the experiments and in each tank, three sediment filled plastic aquaria were half-submerged (Fig 2). One aquarium was used for temperature treatment and remaining two were treated with low and high concentration of diesel oil. Temperature of each large tank was controlled by submerged digital thermostat for the duration of the experiment (60 days). Three temperature treatments were used: a) control temperature (25°C), which corresponded to the ambient pore water temperature at sampling time and b) two elevated temperatures - 30°C & 35°C. A transparent plastic cover in each aquarium was used to prevent evaporation and subsequent salinity changes. During the experiment, salinity was checked daily and adjusted when required using distilled water.

B. Diesel oil contamination

In each large tank two separate doses of diesel were used (one low and one high) for this experiment. 200 kg of sediment in each plastic aquarium were contaminated by appropriate doses of diesel to obtain low concentration (5 mg kg^{-1}) and high concentration (20 mg kg^{-1}). Diesel was introduced into the sediment with the help of a sprayer. Contaminated sediments of each aquarium were topped up with filtered sea water collected during sampling and were aerated using aquarium air stone. In each large tank, one uncontaminated aquarium was maintained as control.

4.3.3 Faunal analyses

Triplicate samples were collected prior to commencement of the experiment (Day 0), after 30 and 60 days from the respective experimental setup. A 50 ml syringe (inner diameter 3 cm) was used to collect the sediment and preserved in buffered Rose Bengal (0.5 g l^{-1}) formalin at a concentration of 4 % (Danovaro et al., 2004) for 24 hours. Meiofaunal organisms were sorted, enumerated and identified to major taxonomic level. From each experimental setup, 100 nematodes were picked for identification according to methodology described in section 4.1.

Statistical analyses

Bray–Curtis similarity index and non-metric multidimensional scaling (nMDS) were constructed based on abundances of meiofauna or nematode (as applicable) after square-root transformation. Similarity profile (SIMPROF) test was carried out to detect significantly important station groups (significance level 0.05). Similarity of percentages (SIMPER) analysis was conducted to identify the key species responsible for the formation of groups. Principal component analysis (PCA) was performed to identify essential environmental variables that characterize the study area. The following ecological indices were determined depending upon nematode abundances: Shannon-Wiener (H′), Margalef's species richness (d) and Pielou's evenness (J′). Analysis of variance (ANOVA) was done to compare the significant temporal and spatial variation of meiofauna and nematode communities. Permutational Multivariate Analysis of Variance (PERMANOVA) was also applied to examine the role of seasonal effect on meiobenthos across Matla river, to explore variation in vertical distribution of meiobenthos among different vegetation & depth and to detect the effects of elevated temperature and diesel

on experimental meiobenthos. All PERMANOVA test were followed by Bray-Curtis similarity matrices under a reduced model using permutation of residuals. All statistical analyses were performed using PRIMER (version 6) software (Clarke and Gorley, 2006; Clarke et al., 2008) equipped with add-on package PERMANOVA (Anderson et al., 2008) and Microsoft Excel. Canonical Correspondence Analysis (CCA) (ter Braak, 1986) was used to assess the relationship between free-living nematode community structure and abiotic factors using the Multivariate Statistical Package (MVSP) (version 3.1) (Kovach, 1998).

5. Results

5.1 Objective 1 & 2

Documentation of spatial and temporal variations in meiobenthic distribution of Sundarban estuarine system and understanding environmental factors influencing distribution pattern of meiobenthic assemblages of aforesaid area.

Part A

Compared to preceding five years, SES experienced massive rainfall during monsoon in 2013. Unlike most of the ecological studies of seasonal variation, intra-seasonal shift of meiobenthic assemblages has never been attempted from Indian coast. During our continuous monitoring program across river Jagaddal, for the first time we investigated the influence of excessive monsoonal rainfall on meiobenthic community selecting fifteen stations along salinity gradient. The average meiofaunal abundances were recorded as 699 ± 1569.4 ind. 10 cm^{-2} and 437 ± 949.9 ind. 10 cm^{-2} during early (EM) and later (LM) phase of monsoon respectively (Fig 3) and revealed a significant differences (ANOVA: $p < 0.05$). In both phases, meiofauna assemblage was dominated by free-living nematodes (87.76% and 84.22% of total meiofauna in EM and LM respectively) followed by another five meiofaunal taxa. Cluster analyses derived from the Bray–Curtis similarity matrix depending upon meiobenthic taxa explained a large group and one separate station (station 13) during EM whereas in LM, two groups were identified (SIMPROF test $p < 0.05$) (Fig 4). SIMPER analysis showed significant contribution of nematodes (54.96%) for the large group formation in EM and 61.72% and 44.85% for the group 1 and group 2 respectively in LM. From both phases of monsoon, a total of 72 nematode species were identified for the first time from SES. CCA biplot for nematode species delineated that

salinity, Chl *a*, SPM, organic carbon (OC) and sediment texture were the most crucial controlling factors for the distribution of nematode communities in both seasons (Fig 5; Table 1). Nematode species like *Sabatieria pulchra*, *Daptonema* sp., *Paralinhomoeus* sp., *Desmoscolex* sp., *Tricoma brevirostris*, *Quadricoma scanica* etc. were associated with OC fraction of sediment since high numbers of these species were found in stations with high OC content. Among sediment texture, sandy and silty substrata of sediment were favoured by *Theristus* sp., *Terschellingia longicaudata*, *Sphaerolaimus* sp., *Paracomesoma dubium* and *Tricoma* sp.; whereas *Daptonema hirsutum*, *Anoplostoma viviparum*, *Araeolaimus penelope* and *Chromadorita nana* were showed preference to high percentage of clay. *Sabatieria lyonessa*, *Rhips paraornata* and *Platycoma* sp. were influenced by elevated salinity. On the other hand, *Metachromadora* sp., *Enoplus* sp., *Diplolaimella* sp., *Chromadora nudicapitata* and *Chomadorita* sp. were not affected by any other abiotic factors. In station biplot (Fig 5B), during EM stations 2 & 3 favoured by sediment temperature, station 6 were associated with pH, station 5 were linked with salinity and station 4 & 9 were profited by SPM. In LM, stations 3, 4, 6, 7, 11, 12 & 13 were influenced by sediment texture, whereas station 14 favoured higher Chl *a* fraction of sediment. Moreover, in the same year, a catastrophic cloud burst phenomenon occurred at upper Himalayan region which might have intensified the precipitation load at SES in manifolds. During later phase of monsoon massive riverine runoff followed by cloudburst phenomenon completely flushed the estuary which might be attributed to reduced abundance of meiobenthic population across the study area. Lack of pelagic larval stages and direct benthic development make juveniles as well as adult meiobenthic organisms more susceptible to changes in sedimentary environment caused by the monsoon mediated wash off. Therefore, our results depicted that change in natural precipitation pattern accompanied by catastrophic events might have detrimental effect on overall distribution pattern of meiobenthos (Altaff et al., 2005; Fattorini et al., 2018).

Paper published in Ecological Indicator - Ghosh et al., (2018)

Part B

Seasonal dynamics of meiofaunal assemblages were assessed across Matla river during four different seasons (monsoon, winter, spring and summer). Total meiofaunal abundance differed significantly among seasons (PERMANOVA, $p < 0.05$) with highest number (±SD) in spring (2978 ± 689.98 ind. 10 cm^{-2}) and lowest in monsoon (405 ± 51.22 ind. 10 cm^{-2}) (Fig 6). Taxonomic composition of meiofauna was constituted by 11 taxa throughout the 8 stations of

Matla during sampling periods with the dominance of free-living nematodes (74%). In order to visualize the impact of crucial abiotic variables, PCA was performed, which depicted a distinct separation of seasons in relation to abiotic variables (Fig 7). Altogether, 79 species of free-living nematode had been identified for the first time from Matla river (Table 2). Five most abundant species, *Sabatieria preadatrix*, *Sphaerolaimus bulticus*, *Terschellingia longicaudata*, *Desmodora communis*, *Dorylaimopsis punctata* and *Daptonema hirsutum* were recorded throughout the study period (Fig 8). Functional diversity of nematodes based on four biological traits or characteristics [feeding type, body & tail shape and life strategy or colonizer-persister (c-p) score] was evaluated to understand multiple aspects of ecosystem functioning (Fig 9). In general, functional structure or diversity of a community is defined as a combination of species distribution and their abundances in the functional space (Mouillot et al., 2013) and biological traits are those characteristics that define species in the context of their ecological roles (Diaz and Cabido, 2001). Most of the nematodes encountered throughout the study were non-selective deposit feeders (1B), which generally prevailed in silty sediment due to food availability (bacterial growth and organic detritus deposition). A significant abundance of slender body and clavate tail shape in each season were observed as an adaption to higher content of silt and clay of the sediment (Schratzberger et al., 2007). Life strategy characterization revealed a dominance of colonizers and intermediate (c-p 2, 3 and 4), suggesting a high stress level with an increase of opportunistic species. Thus, present maiden approach using biological trait analyses from SES indicated overall benthic environmental health in different fashion.

5.2 Objective 3

Study of vertical distribution of meiofauna in response to physico-chemical variables.

A plethora of studies have been attempted to study mangrove-meiofauna interaction from upper layer of mangrove sediments of coastal belt of India (Goldin et al., 1996; Chinnadurai and Fernando, 2003), but deeper layer of sediment remained poorly documented in the context of vertical meiofaunal distribution, abundance and species diversity. The present investigation is a pioneering attempt to explore vertical distribution of meiobenthic community and species composition of nematode from five mangrove vegetation (*Aegiceras corniculatum*, *Avicennia alba*, *Bruguiera gymnorrhiza*, *Rhizophora mangle* and *Sonneratia caseolaris*) at Bali Island of

SES. Among aforementioned mangrove species, *S. caseolaris* (3100 ± 61.54 ind. 10 cm^{-2}) harbored the highest density of meiobenthos and the lowest in *B. gymnorrhiza* (1210 ± 48.11 ind. 10 cm^{-2}). The vertical profiling of meiobenthic composition indicated upper 3–4 cm retained more than 90% of entire faunal assemblages and after that depth they were present in negligible amount in subsequent layers (Fig 10). PERMANOVA result of overall meiobenthic assemblages showed a significant variation between different vegetation and depth ($p < 0.05$). Sediment pore water O_2 as well as H_2S concentration could be critical factors for the reducing number of fauna vertically with increasing depth. Generally in muddy substratum O_2 penetration is restricted to upper few centimeters forming a layer of Redox Potential Discontinuity (RPD) and below that depth H_2S concentration increase, which reflects harmful effect on sediment dual organisms (Dye, 1983; Moodley et al., 2000). In the present study free-living nematodes appeared even up to 15 cm depth, which attributed their well adaption in harsh environment. However, no depth-specific species of nematode were noticed, which suggested their migration through deeper layer of sediment. Although nematode were recorded up to 15 cm of sediment depth, but harpacticoid copepods were generally restricted to upper 3 cm as they were supposed to be sensitive taxon in anoxic sediment than nematodes (De Troch et al., 2013). Howbeit, other controlling factors like available of food (bacteria, algae etc.), organic carbon content, vertical changes in sedimentary pH, O_2 etc. and tannin concentration of mangrove leave appeared to be important factors in framing vertical profile of meiobenthos (Semprucci et al., 2016). It is believed that tannins derived from mangrove leaves could have harmful effects on benthic organisms in tropical mangrove forest (Alongi, 1987). We also recorded low abundance of meiobenthos in tannin rich leave of *Rhizophora* (1348 ± 71 ind. 10cm $^{-2}$) whereas tannin less leave of *Avicennia* harbored higher meiofaunal abundance (1735 ± 52 ind. 10cm $^{-2}$). Altogether 52 nematode species were first time identified from different mangrove species of SES (Fig 11). Epistrate-feeder nematodes dominated the samples, followed by selective deposit feeders, predators and non-selective deposit feeders (Fig 12). Epistrate nematodes were predominant over other trophic guilds due to ample food resources like algae and bacteria biofilm growing on mangrove roots, propagules and leaves. Among the colonizer–persister classes (c-p 1 to 5), c–p 2, 3 and 4 collectively dominated the assemblages, which might be characterized by high ecological quality status of the study area. Extreme persister (c-p 5) species *Enoplus brevis* were also recorded in sediment of *Sonneratia*.

5.3 Objective 4

Observation of the potential environmental disturbances including climate change upon meiobenthic animals.

A 60 days mesocosm experiment was conducted to unravel the synergistic effects of global warming induced temperature elevation and anthropogenic perturbation of petroleum hydrocarbon on meiobenthic communities. Average meiofaunal abundances of experimental communities using 3-factor PERMANOVA indicated a significant effect of temperature (P = 0.001), diesel (P= 0.001), interaction between temperature & diesel (P = 0.001) and interaction among temperature, diesel & time (P = 0.001). At the onset of the experiment (day 0), average meiofaunal abundance in all treatments were ranged from 380 ± 21.78 to 1462 ± 17 comprising 7 to 8 taxa. However, after 30 and 60 days of experiment average meiofaunal abundance decreased significantly and comprised of 51 ± 8.57 to 682 ± 23.02 with 5 to 7 taxa and from 30 ± 8.75 to 387 ± 22.74 with 4 to 5 taxa respectively (Fig 13). Among meiobenthic taxa, nematodes dominated the assemblages throughout the experiment followed by copepod and also displayed extreme shift in abundance in response to treatments. Other meiofauna taxa like, halacarid mite, turbellaria and polycheate juveniles were also significantly affected by treatments, albeit abundance of ostracods, foraminiferans and bivalve settlers were varied significantly. A total of thirty six nematode species were identified during the experimental period. Multivariate nematode species dependent nMDS ordination plot showed the separation of assemblages exposed to diesel (low and high dose) as well as high temperature in relation with time (Fig 14). SIMPER analysis identified nematode species *Daptonema invagiferoum*, *Marylynnia complexa* and *Viscosia abyssorum* were mainly responsible for the similarity between control and treated mesocosm. Graphical representation of univariate indices for nematode community from each mesocosm depicted a clear effect of treatments over time (Fig 15). Total number of nematode species (S), species richness (d), evenness (J') and Shannon – Weaver index (H') decreased considerably with the increase of diesel contamination. Our finding was in agreement with previous experiments by various authors around the globe (Elarbaoui et al., 2015; Kang et al., 2016), where nematode densities and diversities were affected drastically after hydrocarbon pollution. The control mesocosm was characterized by a significant high numbers of *Daptonema invagiferoum*, *Marylynnia complexa* and *Viscosia abyssorum*, which declined in abundance with

increasing level of stressors. Elevated levels of temperature and diesel contamination led to an elimination of K-selected species like *Halalaimus gracilis*, *H. longicaudatus*, *Oxystomina aesetosa* and *Pomponema* sp. with a decrease in abundance of *H. capitulatus* and *Oncholaimus* sp. The abundance of r-selected species *Theristus acer* remained unchanged even at high doses of diesel from three different temperature (25, 30 and 35 °C) set up and could be characterized as 'opportunistic' or 'diesel resistant' species. Therefore, accumulation of hydrocarbon pollutants in sediments entails depletion of dissolved oxygen and Chl *a* content, which are identified as regulating factors for nematode composition (Neira et al., 2001).

6. Conclusion

Present study is the first time documentation on meiofauna, especially nematode species from Sundarban Estuarine System, where intramonsoonal variability among meiobenthic organism and how they adapt to the environmental changes have been assessed. This pioneering study also describes the spatio-temporal and functional structure of meiofauna communities in relation to environmental parameters. 79 species of free-living nematode have been identified for the first time from this ecoregion. Furthermore, this study clarifies the issue regarding vertical distribution of meiofauna along different mangrove vegetation with in depth information on nematode taxonomy. In the milieu of habitat destruction and anthropogenic perturbation, present dataset may assist the policy makers for monitoring of ecosystem and management practices in near future.

Global climate change has tremendous impacts on aquatic fauna and it is conjectured that along with future climatic scenario anthropogenic stressor like oil pollution may cause serious environmental disasters, which jeopardize benthic habitat. The present research also highlights synergistic impact of elevated temperature and oil pollution by conducting a 60 days mesocosm experiment and showed deleterious effects of these stressors on benthic species composition and abundance. In milieu of climate change scenario our observation would be a pioneering footstep to understand the effect of anthropogenic changes upon meiobenthos.

References:

Alongi, D.M., 1987. The influence of mangrove derived tannins on intertidal meiobenthos in tropical estuaries. Oecologia 71, 537–540.

Altaff, K., Sugumaran, J., Naveed, Md.S., 2005. Impact of tsunami on meiofauna of Marina Beach, Chennai, India. Curr. Sci. 89 (1), 34–38.

Armenteros, M., Perez-Garcıa, J.A., Perez-Angulo, A., Williams, J.P., 2008. Efficiency of extraction of meiofauna from sandy and muddy marine sediments. Rev. Invest. Mar. 29 (2), 113–118.

Bezerra, T.N., Decraemer, W., Eisendle-Flöckner, U., Hodda, M., Holovachov, O., Leduc, D., Miljutin, D., Mokievsky, V., Peña Santiago, R., Sharma, J., Smol, N., Tchesunov, A., Venekey, V., Zhao, Z., Vanreusel, A., 2019. Nemys: World Database of Nematodes. Accessed at http://nemys.ugent.be on 2019-08-27. doi:10.14284/366.

Bongers, T., 1990. The maturity index: an ecological measure of environmental disturbance based on nematode species composition. Oecologia 83, 14–19.

Bongers, T., Alkemade, R., Yeates, G.W., 1991. Interpretation of disturbance-induced maturity decrease in marine nematode assemblages by means of the Maturity Index. Mar. Ecol. Prog. Ser. 76, 135–142.

Bongers, T., de Goede, R.G.M., Korthals, G.W., Yeates, G.W., 1995. Proposed changes of cp classification for nematodes. Russ. J. Nematol. 3 (1), 61–62.

Coull, B.C., 1999. Role of meiobenthos in estuarine soft-bottom habitats. Aust. J. Ecol. 24, 327–343.

Danovaro, R., Gambi, C., Mirto, S., Sandulli, R., Ceccherelli, V.U., 2004. Meiofauna . Biol. Mar. Mediterr. 11, 55–97.

De Troch, M., Roelofs, M., Riedel, B., Grego, M., 2013. Structural and functional responses of harpacticoid copepods to anoxia in the Northern Adriatic: an experimental approach. Biogeosciences 10, 4259–4272.

Dey, M., Ganguly, D., Chowdhury, C., Majumder, N., Jana, T.K., 2012. Intra-annual variation of modern foraminiferal assemblage in a tropical mangrove ecosystem. Wetlands 32 (5), 813–826.

Diaz, S., Cabido, M., 2001. Vive la difference: plant functional diversity matters to ecosystem processes. Trends Ecol. Evol. 16, 646–655.

Dye, A.H., 1983. Vertical and horizontal distribution of meiofauna in mangrove sediments in Transkei. S. Afr. Est. Coast. Shelf Sci. 16 (6), 591–598.

El Wakeel, S.K., Riley, J.P., 1957. The determination of organic carbon in the marine muds. ICES J. Mar. Sci. 22 (2), 180–183.

Elarbaoui, S., Richard, M., Boufahja, F., Mahmoudi, E., Thomas-Guyon, H., 2015. Effect of crude oil exposure and dispersant application on meiofauna: an intertidal mesocosm experiment. Environ. Sci. Process Impacts 17 (5), 997–1004.

Fattorini, S., Lorenzo, T. Di., Galassi, D.M.P., 2018. Earthquake impacts on microcrustacean communities inhabiting groundwater-fed springs alter species-abundance distribution patterns. Sci. Rep. 8 (1), 1501.

Folk, R.L., 1968. Petrology of Sedimentary Rocks. Hemphills, Austin, TX.

Harrison, P.J., Khan, N., Yin, K., Saleem, M., Bano, N., Nisa, M., Ahmed, S.I., Rizvi, N., Azam, F., 1997. Nutrient and phytoplankton dynamics in two mangrove tidal creeks of the Indus river delta Pakistan. Mar. Ecol. Prog. Ser. 157, 13–19.

Heip, C., Vincx, M., Vranken, G., 1985. The ecology of marine nematodes. Oceanogr. Mar. Biol. Annu. Rev. 23, 399–489.

Kang, T., Oh, J., Hong, J., Kim, D., 2016. Effect of the Hebei Spirit Oil Spill on Intertidal Meiofaunal Communities in Taean, Korea. Mar. Poll. Bull. 113, 444–453.

Kovach, W.L., 1998. MVSP–multi-variate statistical package for windows, Ver 3.0. Kovach computing services, Pentraeth.

Moodley, L., Chen, G.T., Heip, C., Vincx, M., 2000. Vertical distribution of meiofauna in sediments from contrasting sites in the Adriatic Sea: clues to the role of abiotic versus biotic control. Ophelia 53, 203–212.

Mouillot, D., Graham, N.A.J., Ville´ger. S., Mason, N.W.H., Bellwood, D.R., 2013. A functional approach reveals community responses to disturbances. Trends Ecol. Evol. 28, 167–177.

Neira, C., Sellanes, J., Soto, A., Gutie´rrez, D., Gallardo, V.A., 2001. Meiofauna and sedimentary organic matter off Central Chile: response to change caused by the 1997–1998 El Nin˜o. Oceanol. Acta 24, 313–328.

Papa, F., Durand, F., Rossow, W.B., Rahman, A., Bala, S.K., 2010. Satellite altimeter derived monthly discharge of the Ganga-Brahmaputra River and its seasonal to interannual variations from 1993 to 2008. J. Geophys. Res. 115, C12013. http://dx.doi. org/10.1029/2009JC006075.

Pfannkuche, O., Thiel, H., 1988. Sample processing. In: Higgins, R.P., Thiel, H. (Eds.), Introduction to the study of Meiofauna, Smithsonian Institute Press, Washington, DC, pp. 134–145.

Platt, H.M., Warwick, R.M., 1983. Free living marine nematodes, Part I, British Enoplids, Pictorial key to world genera and notes for the identification of British species. In: Kermack, D.M., Barnes, R.S.K. (Eds.), Synopses of the British Fauna. Cambridge University Press, Cambridge, pp. 1–307.

Platt, H.M., Warwick, R.M., 1988. Free living marine nematodes, Part II, British Chromodorids, Pictorial key to world genera and notes for the identification of British species. In: Kermack, D.M., Barnes, R.S.K. (Eds.), Synopses of the British Fauna (new series). Brill/Backhuys, Leiden, pp. 1–502.

Rao, G.C., Misra, A., 1983. Studies on the meiofauna of Sagar Island. Proc. Indian Acad. Sci. (Anim. Sci.) 92 (1), 73–85.

Schratzberger, M., Warr, K., Rogers, S.I., 2007. Functional diversity of nematode community in the south-western North Sea. Mar. Environ. Res. 63, 368–389.

Schratzberger, M., Ingels, J., 2017. Meiofauna matters: the roles of meiofauna in benthic ecosystems. J. Exp. Mar. Biol. Ecol. 502, 12–25.

Semprucci, F., Balsamo, M., Sandulli, R., 2016. Assessment of the ecological quality (EcoQ) of the venice lagoon using the structure and biodiversity of the meiofaunal assemblages. Ecol. Indic. 67C, 451–457.

Sen, A., Ghosh, M., Khanderao, P., Das, S.K., Roy Chowdhury, D., Sarkar, P.K., Saha, R., Bhadury, P., 2016. Modern benthic foraminiferal assemblages from the world's largest deltaic mangrove ecosystem, the Sundarbans. Mar. Biodiv. 46, 421–431.

Soetaert, K., Muthumbi, A., Heip, C., 2002. Size and shape of ocean margin nematodes: morphological diversity and depth-related patterns. Mar. Ecol. Prog. Ser. 242, 179–193.

Strickland, J.D.H., Parsons, T.R., 1972. A practical handbook of seawater analysis. B. Fish. Res. Board Can. 167, 1–310.

ter Braak, C.J.F., 1986. Canonical correspondence analysis: a new eigen vector technique for multivariate direct gradient analysis. Ecology 67, 1167–1179.

Thistle, D., Lambshead, P.J.D., Sherman, K.M., 1995. Nematode tail-shape groups respond to environmental differences in the deep sea. Vie et Milieu 45, 107–115.

Vanaverbeke, J., Merckx, B., Degraer, S., Vincx, M., 2011. Sediment-related distribution patterns of nematodes and macrofauna: two sides of the benthic coin? Mar. Environ. Res. 71, 31–40.

Vincx, M., 1996. Meiofauna in marine and brackish water sediments. In: Hall, G.S., (Eds.) Methods for examination of organismal diversity in soils and sediments. CAB International, Wallingford, pp. 187–195.

Warwick, R.M., Platt, H.M., Somerfield, P.J.D., 1998. Free-living marine nematodes, Part III, Monhysterids, Pictorial key to world genera and notes for the identification of British

species. In: Kermack, D.M., Barnes, R.S.K. (Eds.), Synopses of the British Fauna (New series). Field Studies Council, Shrewsbury, UK, pp. 1–296.

Wieser, W., 1953. Die Beziehung zwischen Mundhöhlengestalt, Ernährungswiese und 1000 Vorkommen bei freilebenden marinen Nematoden. Ark. für Zool. 4, 439–484.

Zeppilli, D., Sarrazin, J., Leduc, D., Arbizu, P.M., Fontaneto, D., Fontanier, C., Gooday, A.J., Kristensen, R.M., Ivanenko, V.N., Sorensen, M.V., Vanreusel, A., Thébault, J., Mea, M., Allio, N., Andro, T., Arvigo, A., Castrec, J., Danielo, M., Foulon, V., Fumeron, R.,Hermabessiere, L., Hulot, V., James, T., Langonne-Augen, R., Le Bot, T., Long, M., Mahabror, D., Morel, Q., Pantalos, M., Pouplard, E., Raimondeau, L., Rio-Cabello, A.,Seite, S., Traisnel, G., Urvoy, K., Van Der Stegen, T., Weyand, M., Fernandes, D., 2015. Is the meiofauna a good indicator for climate change and anthropogenic impacts? Mar. Biodiv. 45, 505–535.

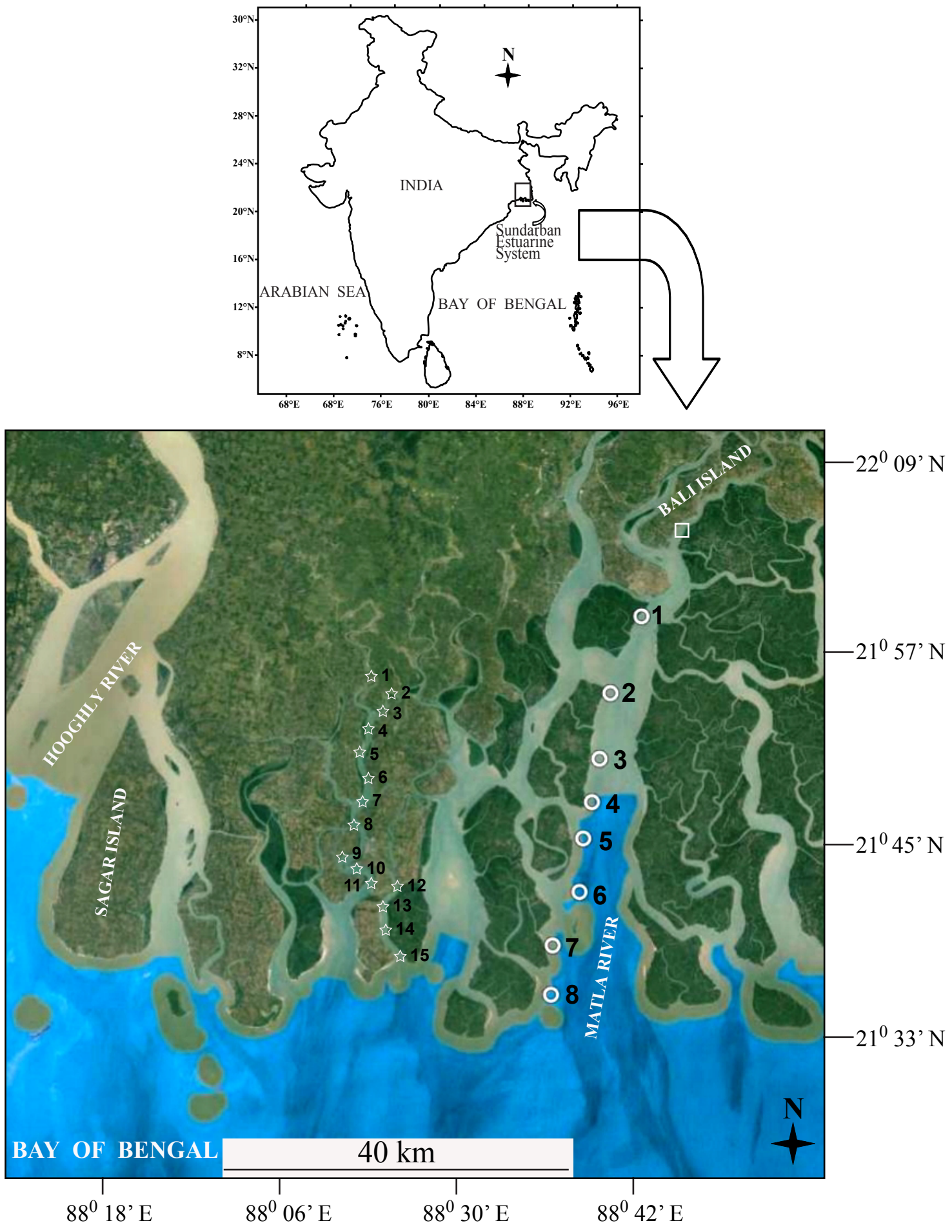


Fig 1: Map showing sampling locations at SES. Star: River Jagaddal (tributary of river Saptamukhi), Circle: River Matla and Square: Vertical profiling study area.

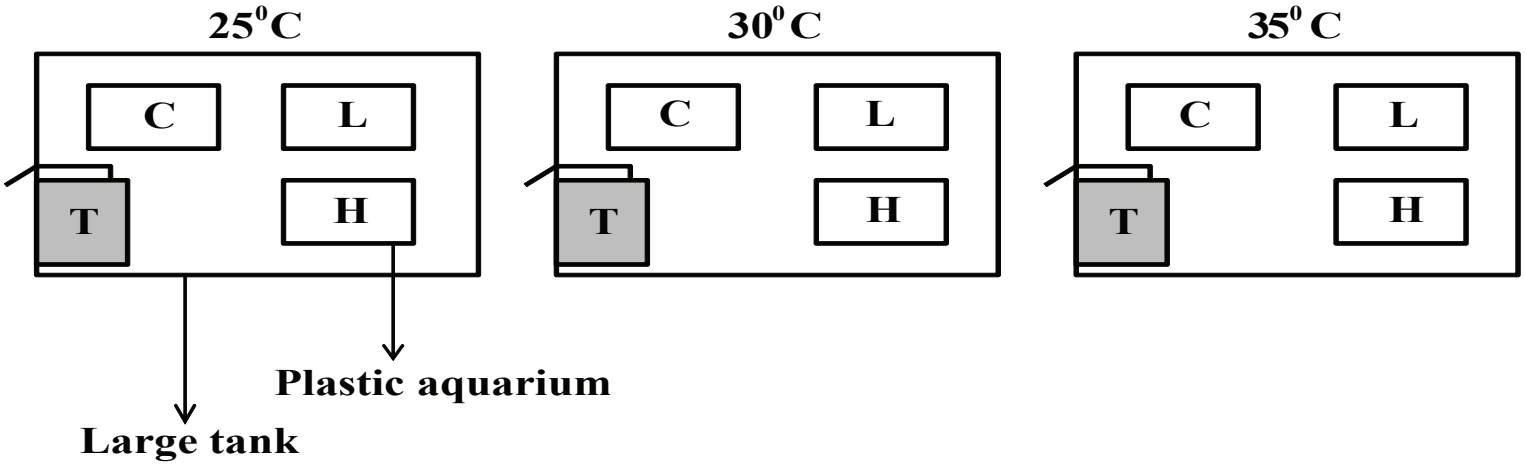


Fig 2: Schematic diagram of the experimental setup; C = Control;
L = Low concentration of diesel oil; H = High concentration of diesel oil;
T = Digital Thermostat for regulating constant temperature

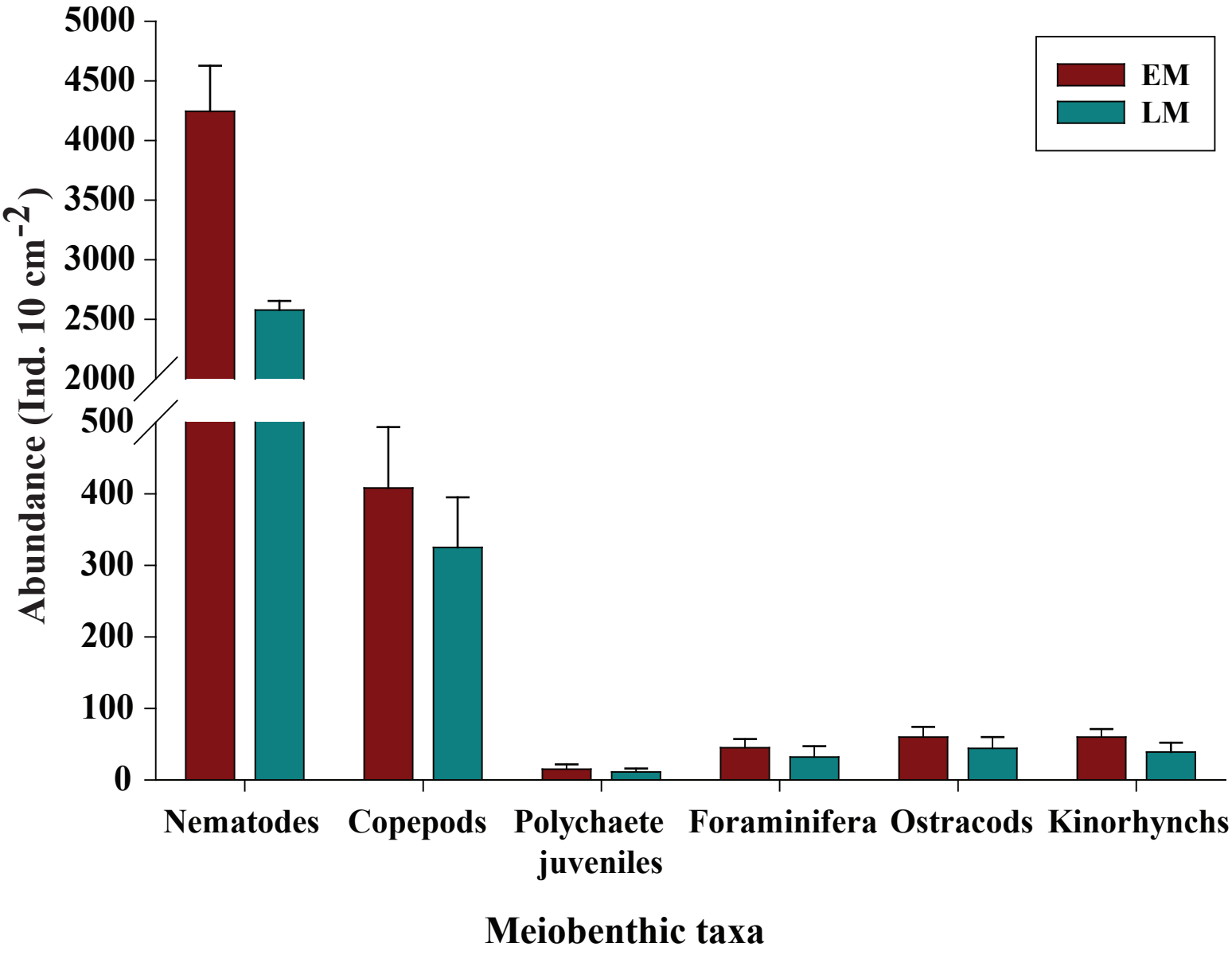


Fig 3: Variation in meiobenthic groups during early (EM) and late (LM) phases of monsoon.

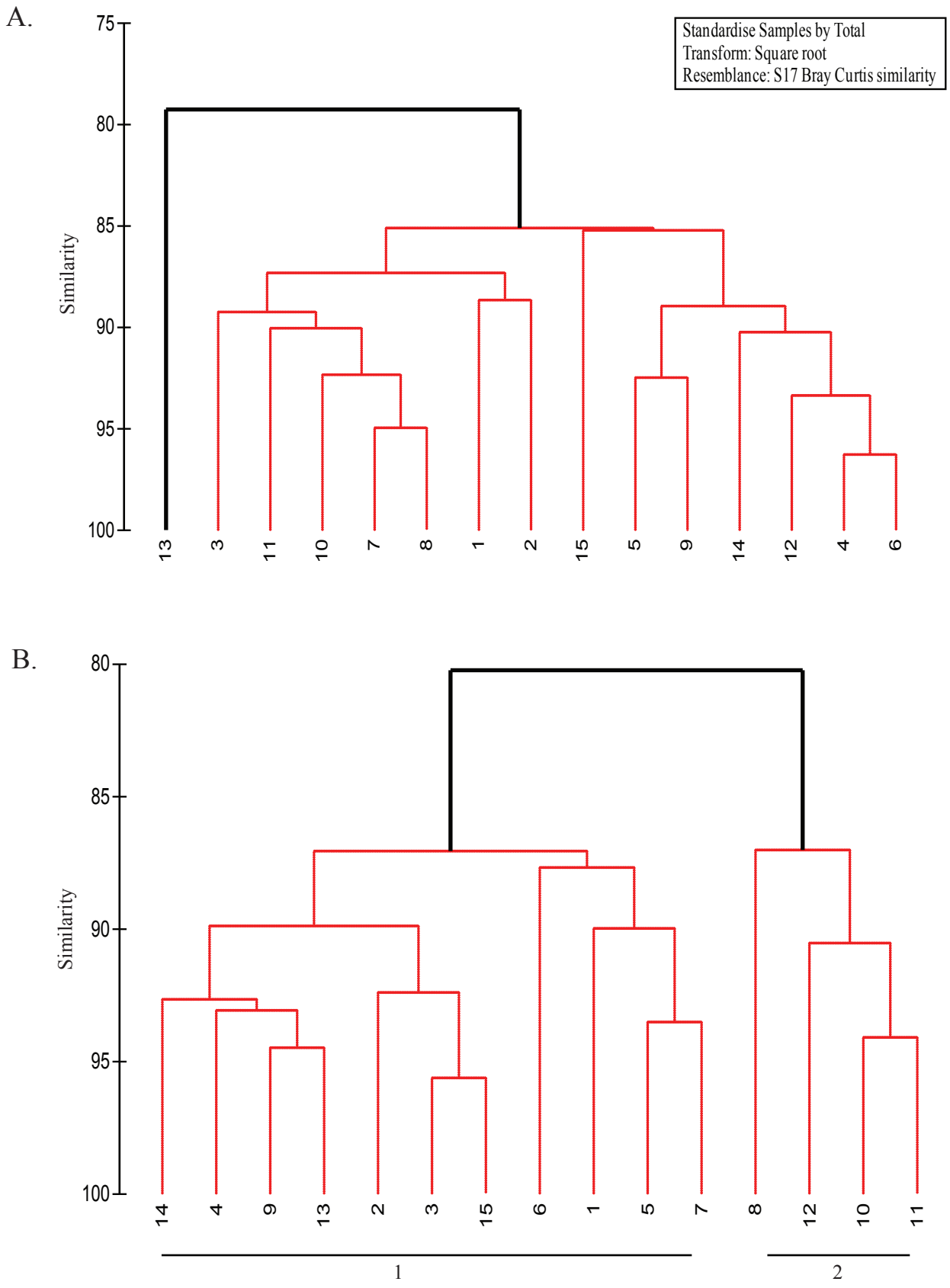


Fig 4: Cluster plot based on Bray–Curtis similarity coefficient of meiobenthic species during two different phases of sampling periods: A. EM and B. LM.

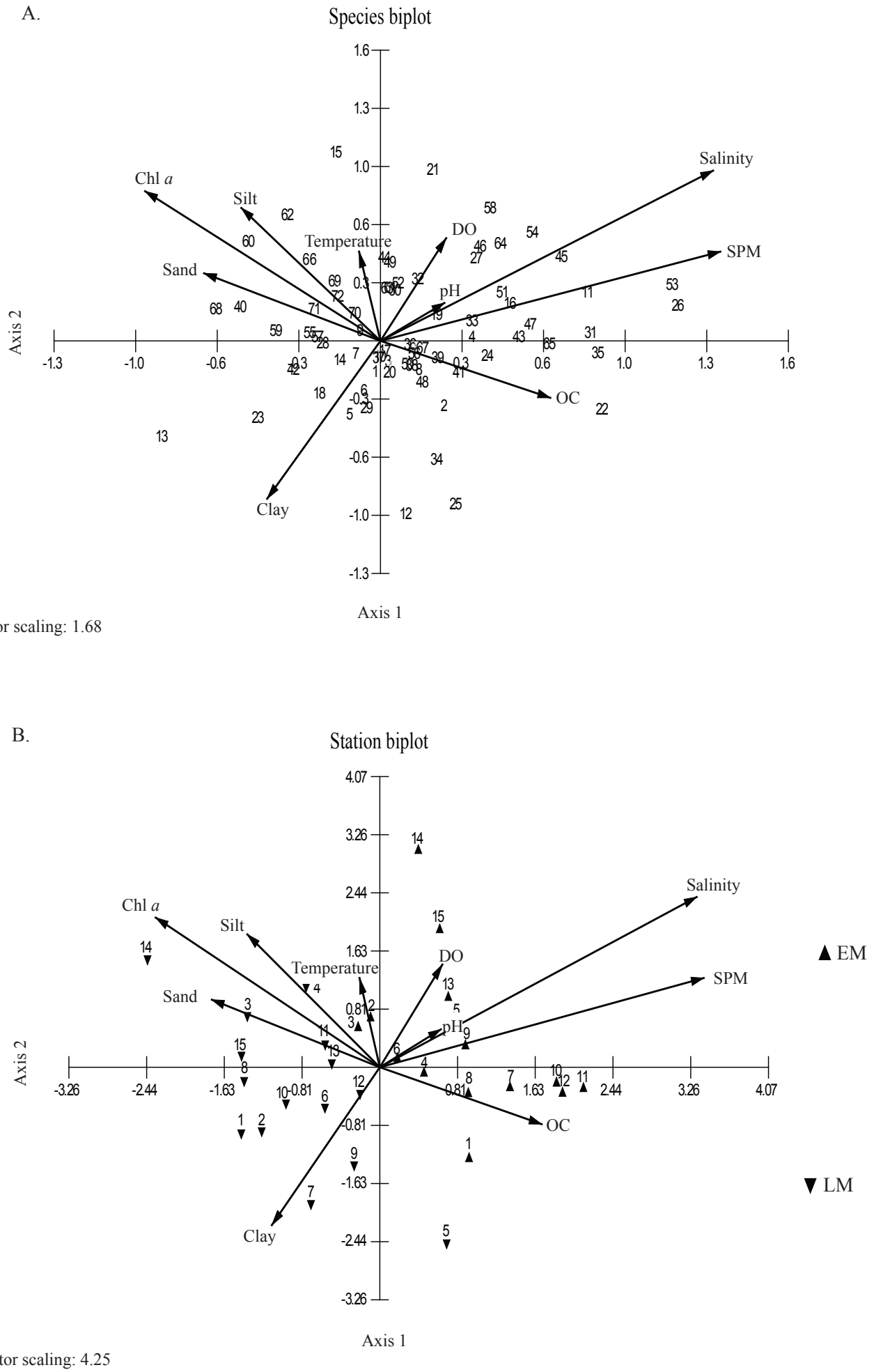


Fig 5: Ordination diagrams for A. species and B. stations based on canonical corresponding analysis (CCA) of free-living nematode community during early (EM) and later monsoon (LM).
The environmental variables (Temperature, pH, DO, salinity, Chl *a*, SPM, sand, silt, clay, OC) are indicated by arrows. Species codes are given in Table 1.

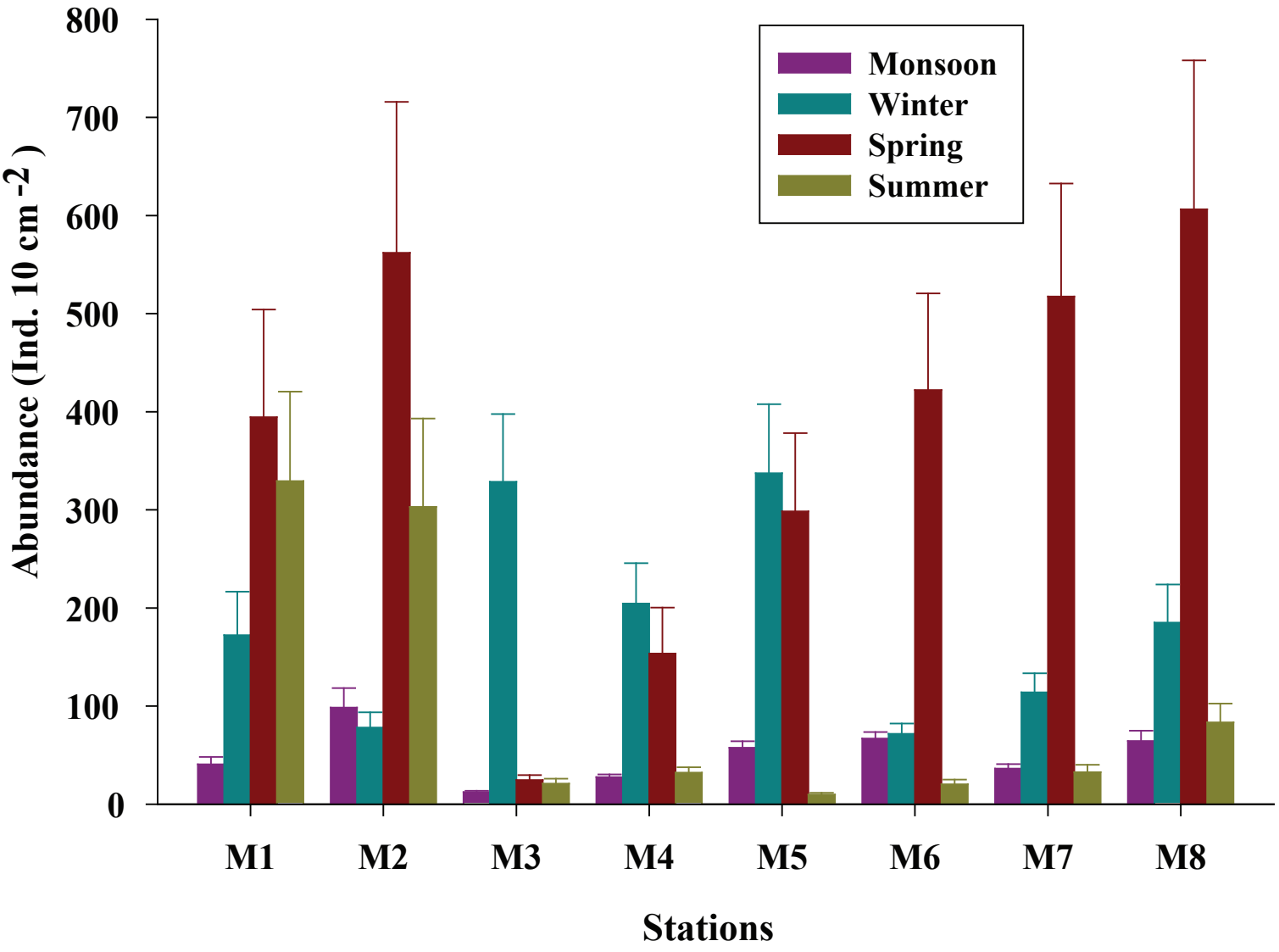


Fig 6: Seasonal variations of meiobenthic population across eight stations (M1 to M8) of Matla (M) river.

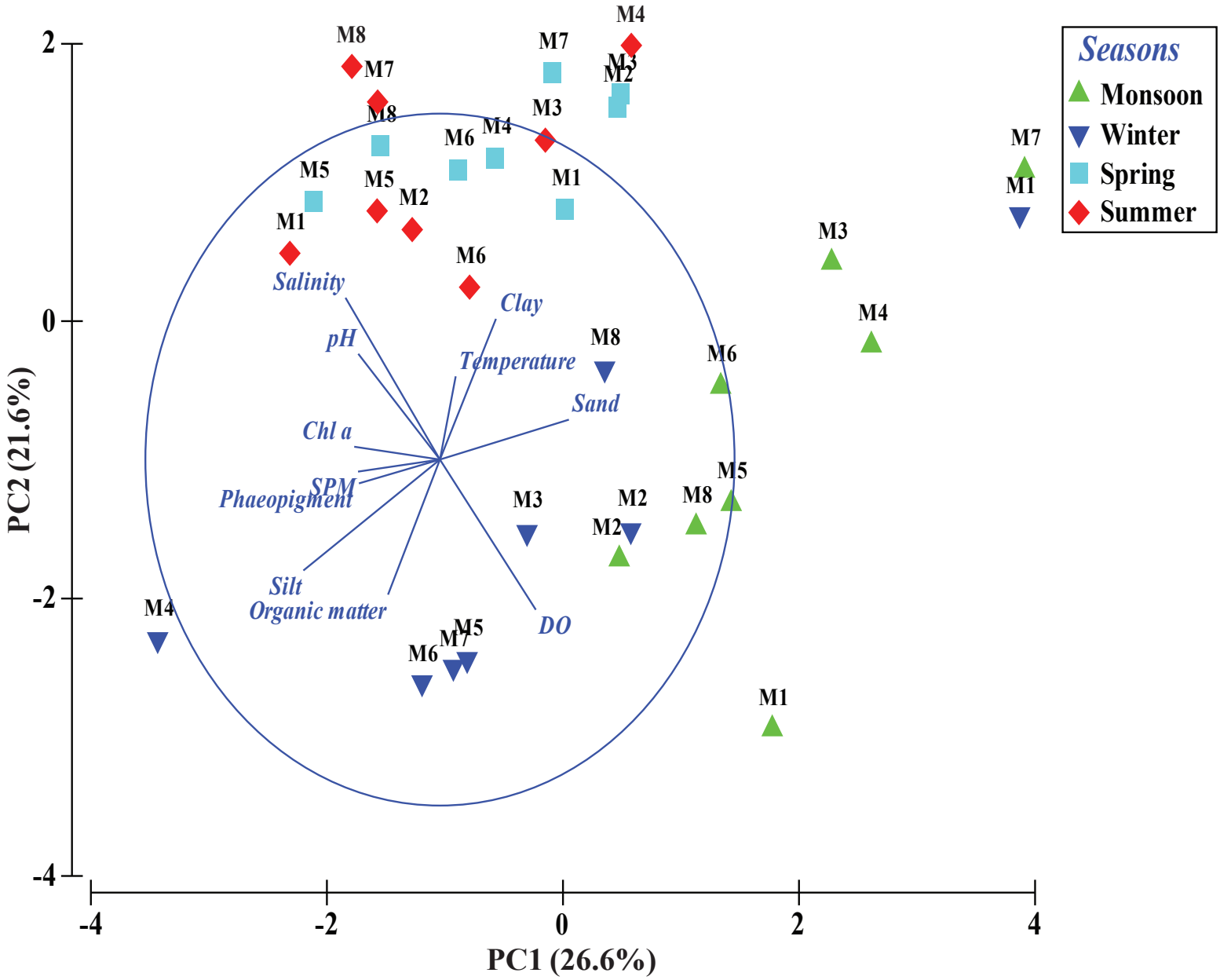
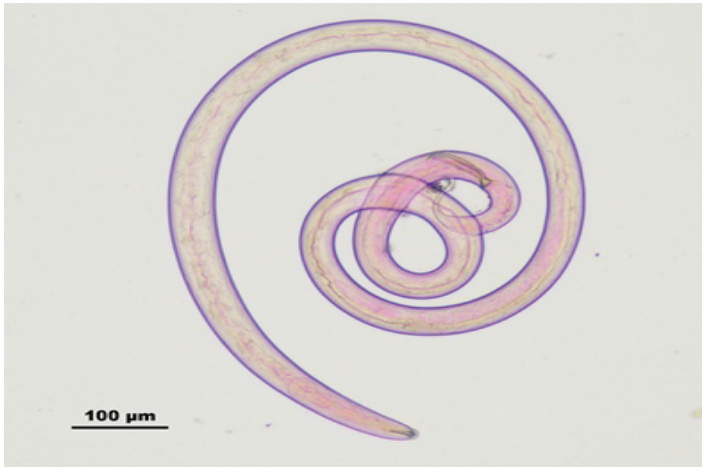


Fig 7: Principal Component Analysis (PCA) based on abiotic variables of four different seasons across eight stations (M1 to M8) from Matla (M) river.

Sabatieria praedatrix

Sphaerolaimus bulticus



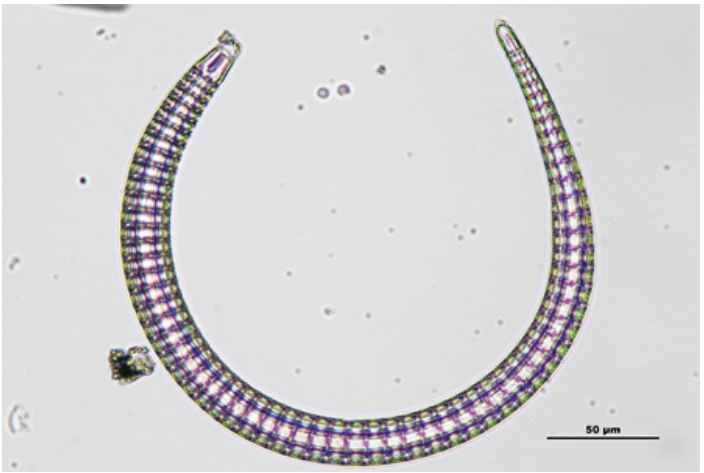
Dorylaimopsis punctata

Daptonema hirsutum

Desmodora communis

Quadricoma scanica

Terschellingia longicaudata



Pselionema longiseta

Fig 8: Dominant nematode species first time recorded from Matla river of Sundarbans.

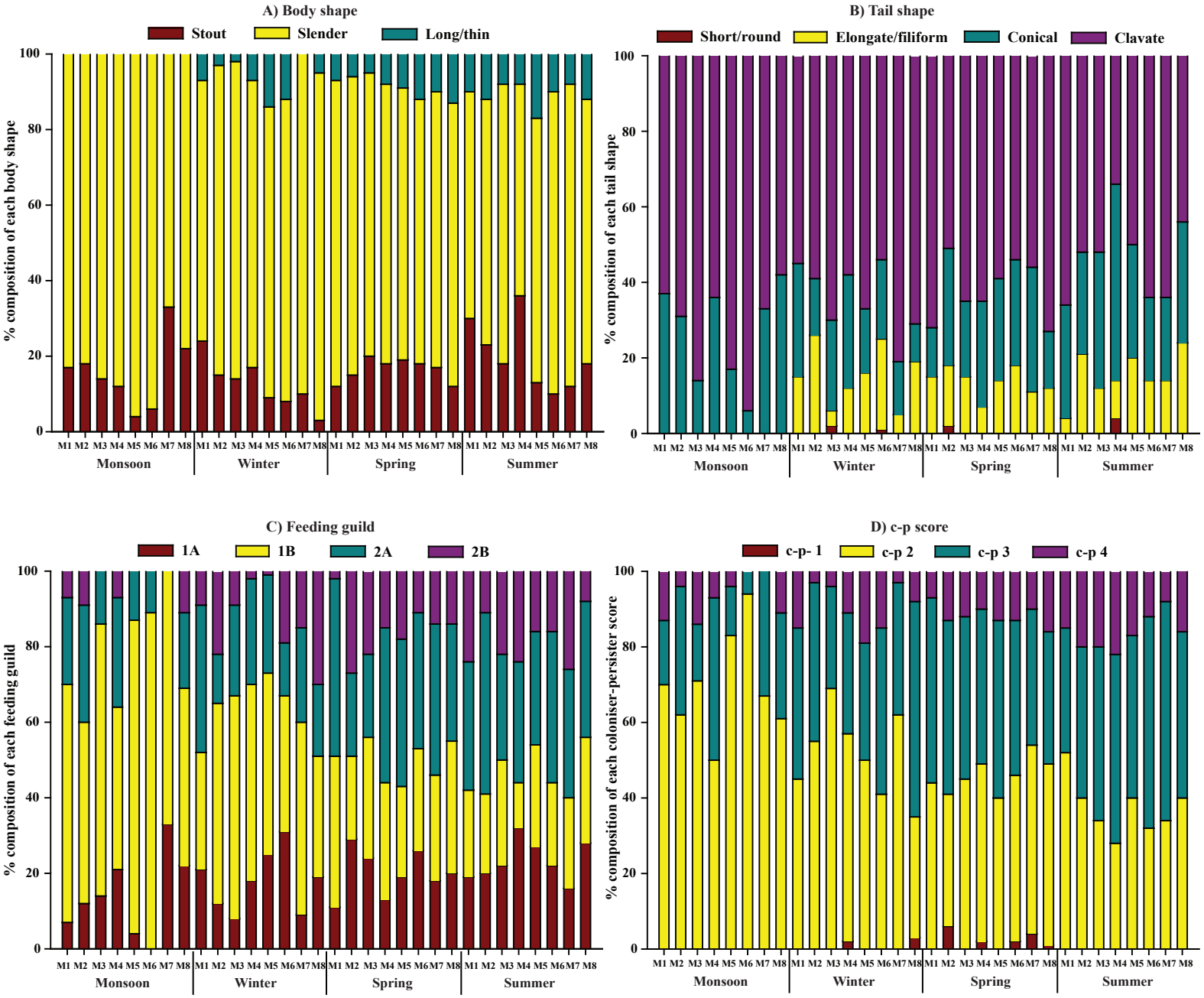


Fig 9: Percentage of trait categories for nematode assemblages across eight stations (M1 to M8) from Matla (M) river.

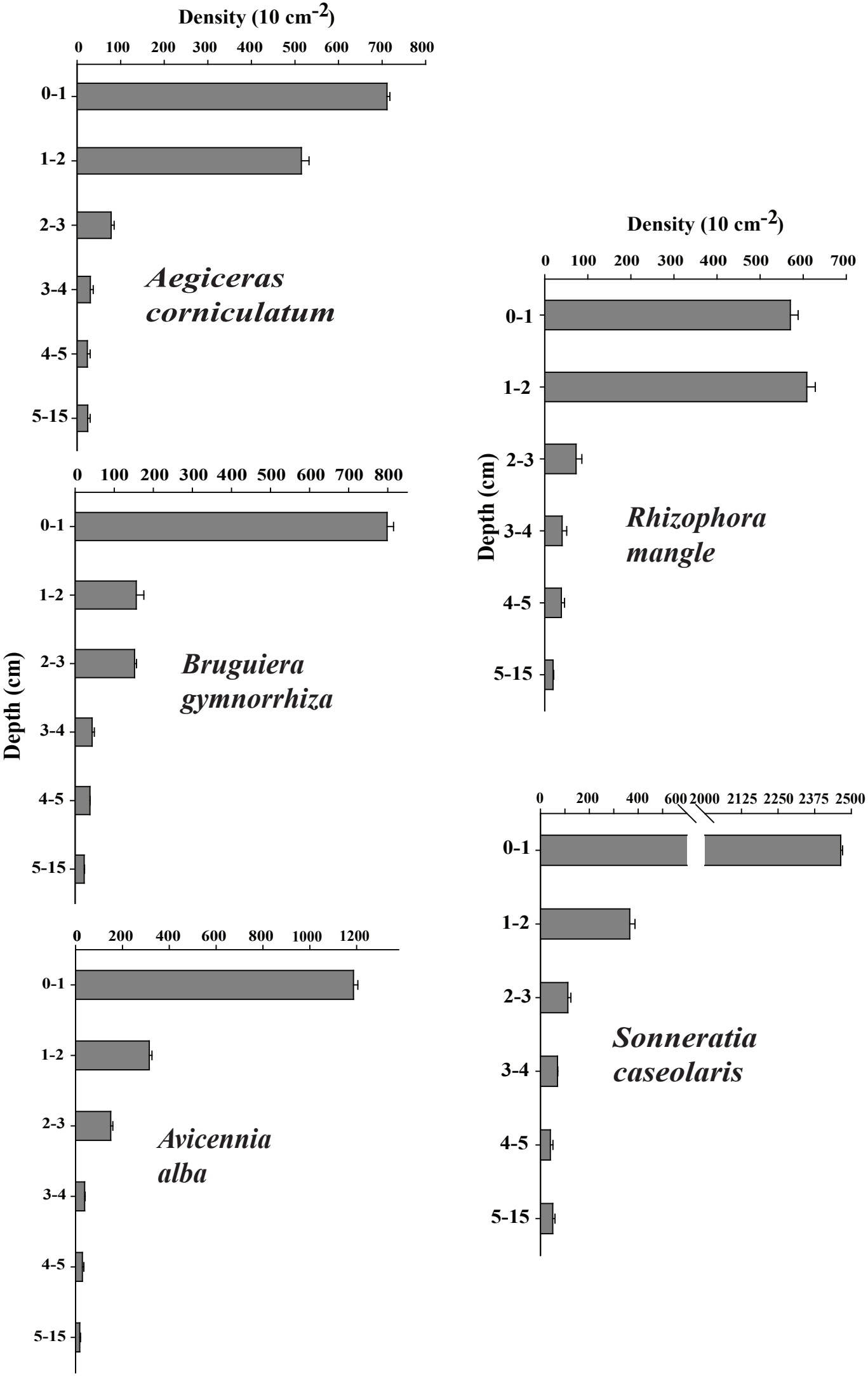
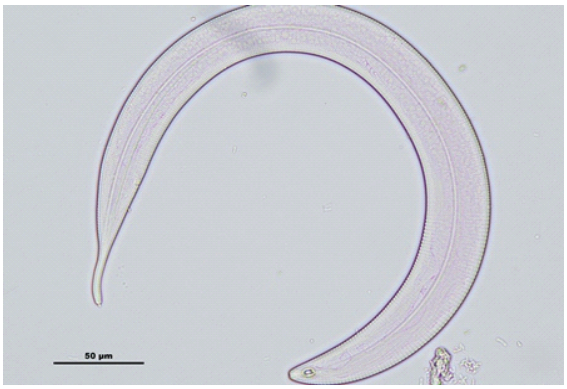


Fig 10: Vertical profile of meiofauna (Mean ± SD 10 cm $^{-2}$) in different mangrove vegetation.

***Actinonema* sp.**



Antomicron elegans

***Polygastrophora* sp.**

Terschellingoides filiformis

Metachromadora vivipara

Viscosia glabra

Desmodora scaldensis

Trissonchulus obtusus

Fig 11: Nematode species identified from five mangrove vegetation of Sundarbans.

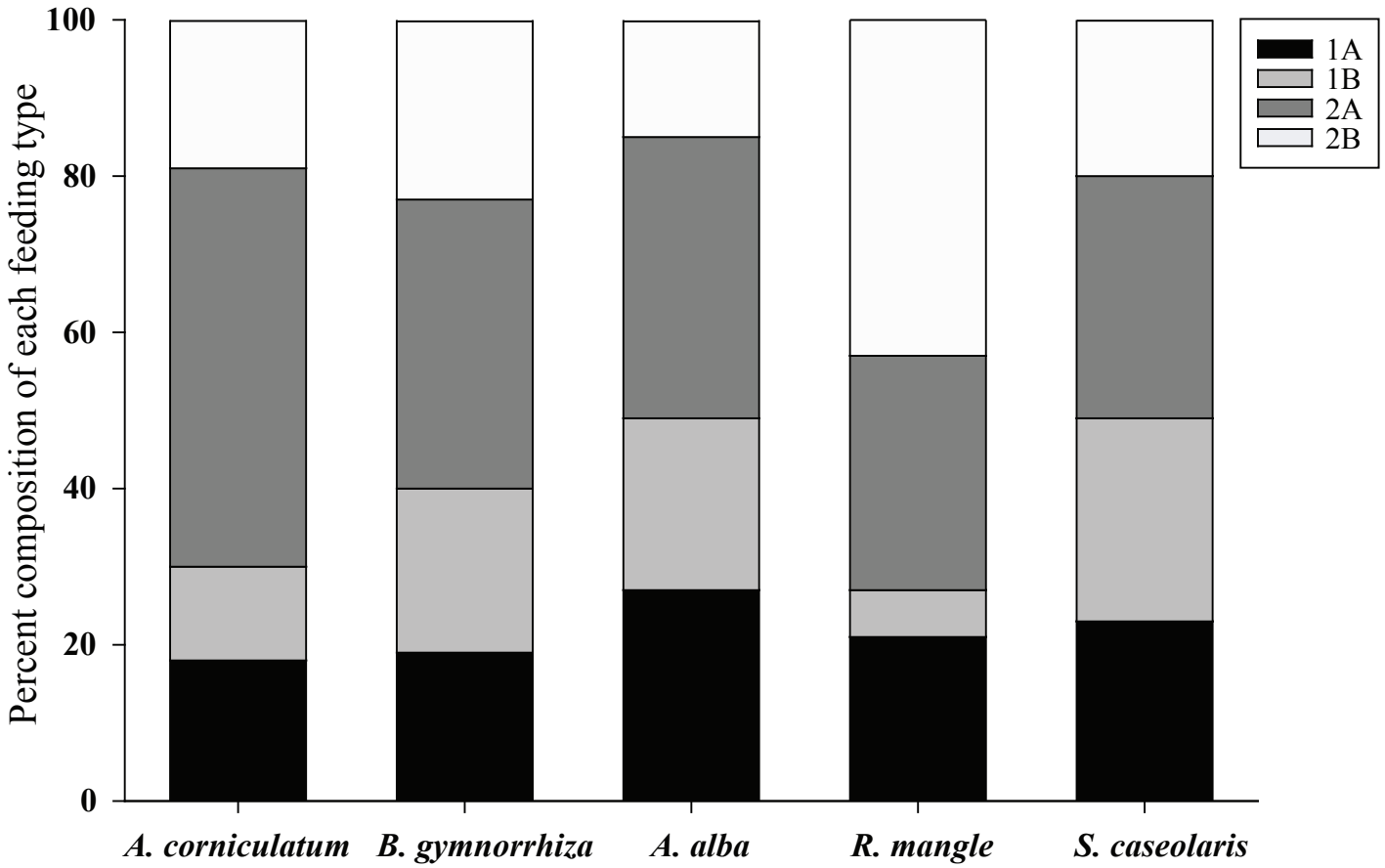


Fig 12: Percent composition of each feeding type of nematodes from five different mangrove vegetation. 1A - Selective deposit feeders; 1B - Non-selective deposit feeders; 2A - Epistrate feeders and 2B - Carnivorous/omnivorous

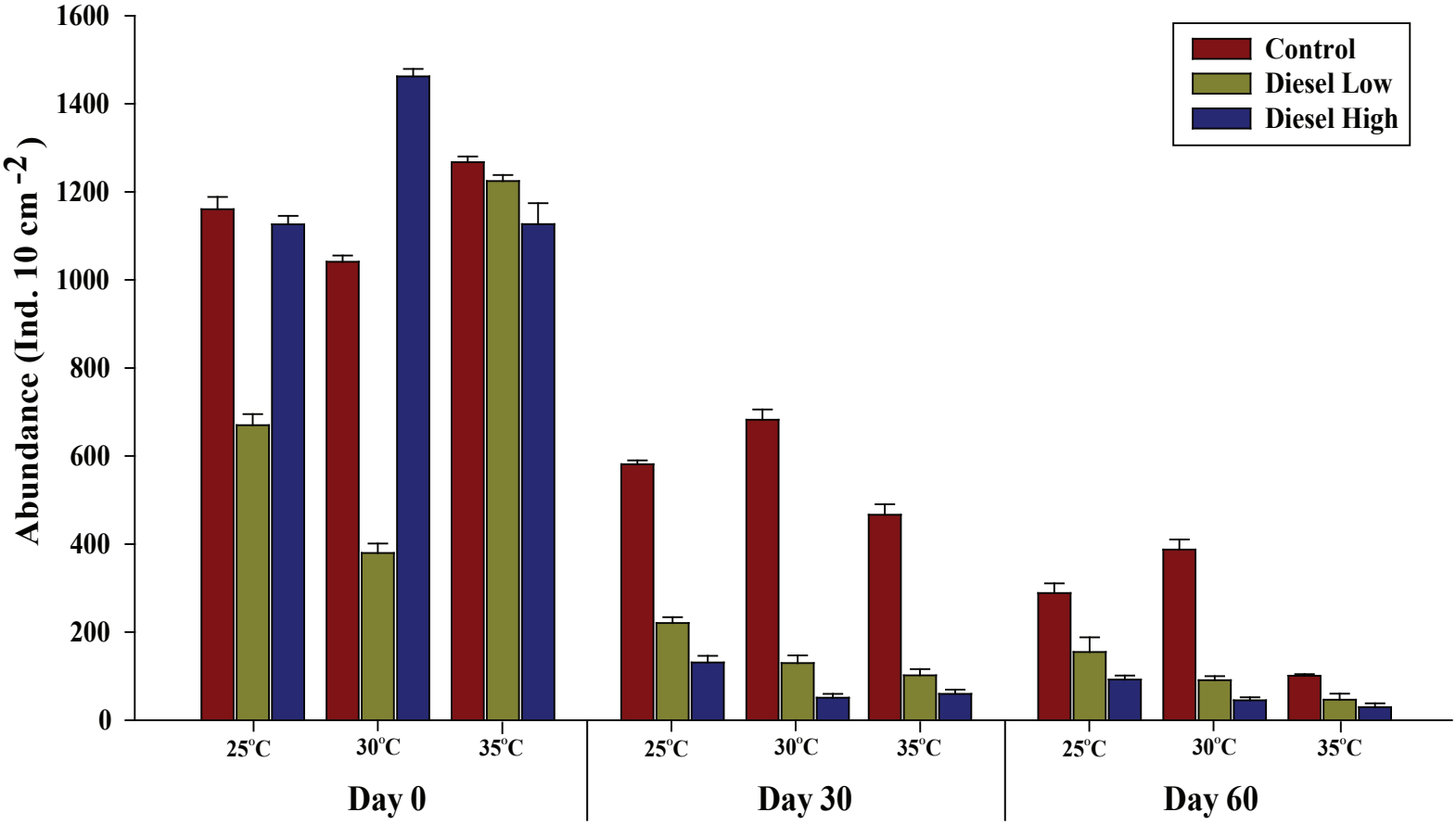


Fig 13: Average meiobenthic abundances observed during the mesocosm experiment.

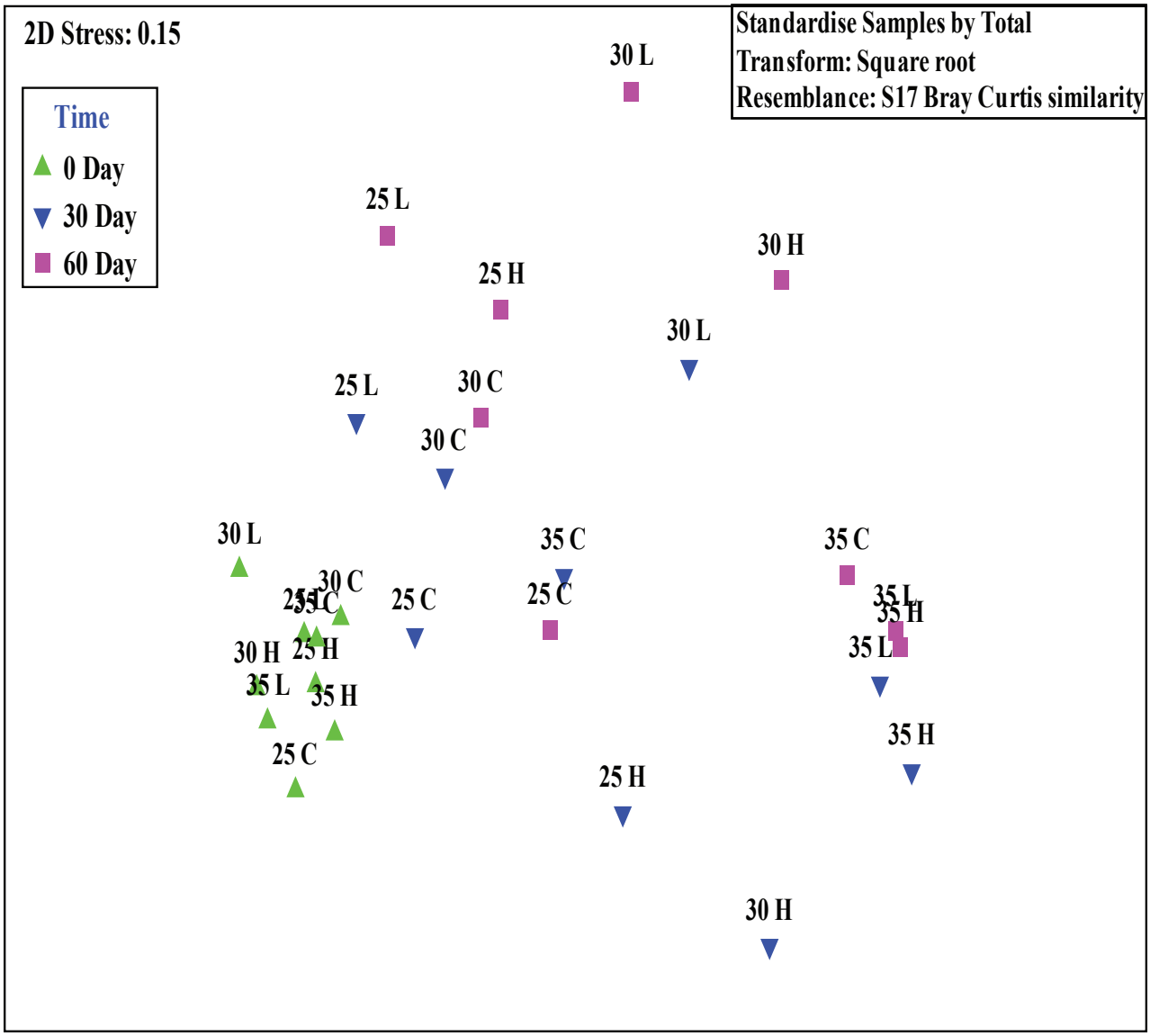


Fig 14: nMDS ordination plot of nematode species abundance data from two different treatments (temperature and diesel pollution).

25: 25° C, 30: 30° C, 35: 35° C;

C: Control, L: Low concentration of diesel, H: High concentration of diesel.

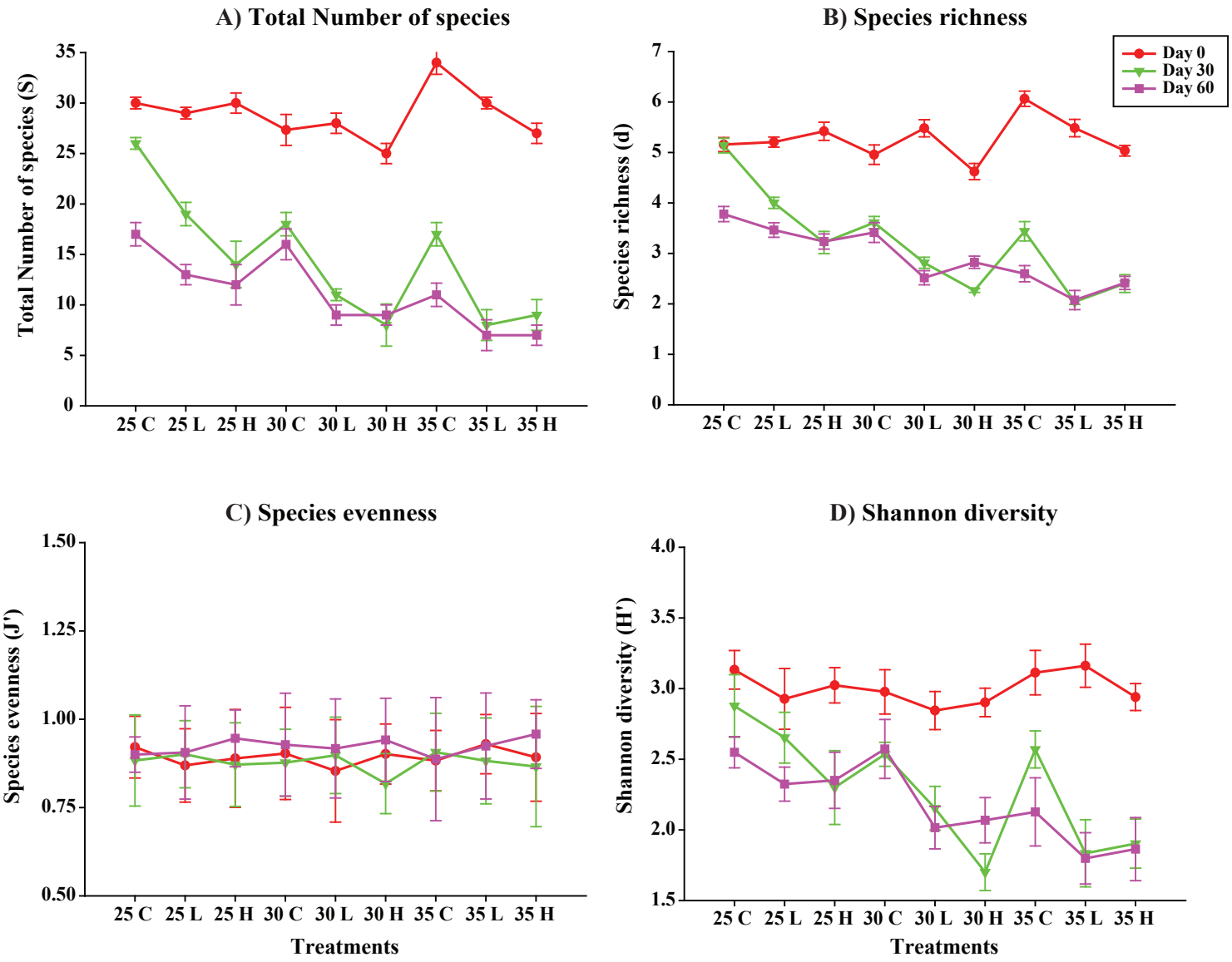

A) Total Number of species
Total Number of species (S)
B) Species richness
Species richness (d)
Day 0
Day 30
Day 60
C) Species evenness
Species evenness (J')
D) Shannon diversity
Shannon diversity (H')
25 C 25 L 25 H 30 C 30 L 30 H 35 C 35 L 35 H
Treatments

Fig 15: Graphical summary of univariate indices for nematode assemblages from each mesocosm.
25: 25° C, 30: 30° C, 35: 35° C;
C: Control, L: Low concentration of diesel, H: High concentration of diesel.

Table 1: List of free-living marine nematode species with CCA code encountered during EM & LM
'+' and '−' indicate present and absent respectively

Species	CCA Code	EM	LM
Anoplostoma viviparum	1	+	+
Anticoma sp.	2	+	+
Aponema sp.	3	+	+
Araeolaimus elegans	4	+	+
Araeolaimus penelope	5	+	+
Araeolaimus sp.	6	+	+
Axonolaimus paraspinosus	7	+	+
Axonolaimus sp.	8	+	+
Camacolaimus sp.	9	+	+
Ceramonema sp.	10	+	+
Chromadorella sp.	11	+	+
Chromadora nudicapitata	12	+	+
Chromadora sp.	13	−	+
Chromadorita nana	14	−	+
Chromadorita sp.	15	+	+
Comesoma sp.	16	+	+
Daptonema sp.	17	+	+
Daptonema hirsutum	18	+	+
Daptonema normandicum	19	+	+
Desmoscolex sp.	20	+	+
Diplolaimella sp.	21	+	−
Doliolaimus sp.	22	+	−
Dorylaimopsis punctata	23	+	+
Dorylaimopsis sp.	24	+	+
Enoplus sp.	25	+	+
Eumorpholaimus sp.	26	+	−
Halalaimus gracilis	27	+	+
Halalaimus sp.	28	+	+
Haliplectus dorsalis	29	+	+
Leptolaimus sp.	30	+	+
Linhystera sp.	31	+	+
Marylynnia complexa	32	+	+
Marylynnia sp.	33	+	+
Metachromadora sp.	34	+	+
Metalinhomoeus sp.	35	+	+
Monhystera sp.	36	+	+
Monoposthia costata	37	+	+
Monoposthia sp.	38	+	+
Oxystomina asetosa	39	+	+
Paracomesoma dubium	40	+	+
Paralinhomoeus sp.	41	+	+

Paracanthonchus sp.	42	+	+
Paralongicyatholaimus sp.	43	+	+
Parodontophora sp.	44	+	+
Platycoma sp.	45	+	+
Praeacanthonchus sp.	46	+	+
Pselionema longiseta	47	+	+
Ptycholaimellus sp.	48	+	+
Quadricoma sp.	49	+	+
Quadricoma scanica	50	+	+
Rhips paraornata	51	+	+
Sabatieria bulticus	52	+	+
Sabatieria elongata	53	+	−
Sabatieria lyonessa	54	+	+
Sabatieria praedatrix	55	+	+
Sabatieria pulchra	56	+	+
Sabatieria sp.	57	+	+
Siphonolaimus sp.	58	+	+
Sphaerolaimus balticus	59	+	+
Sphaerolaimus sp.	60	+	+
Terschellingia communis	61	+	+
Terschellingia longicaudata	62	+	+
Terschellingia sp.	63	+	+
Thalassironus britannicus	64	+	+
Thalassironus sp.	65	+	+
Theristus sp.	66	+	+
Tricoma brevirostris	67	+	+
Tricoma sp.	68	+	+
Vasostoma sp.	69	+	+
Viscosia abyssorum	70	+	+
Viscosia cobbi	71	+	+
Viscosia sp.	72	+	+

Table 2: List of free-living marine nematode species identified from Matla river.
'+' and '−' indicate present and absent respectively

Sl. No.	Species	Monsoon	Winter	Spring	Summer
1	*Anticoma* sp.	−	−	−	+
2	*Antomicron elegans*	−	−	+	−
3	*Aponema* sp.	−	+	+	−
4	*Aponema torosa*	−	+	+	−
5	*Axonolaimus paraspinosus*	+	+	−	−
6	*Axonolaimus* sp.	−	+	+	−
7	*Camacolaimus barbatus*	−	+	−	−
8	*Chromadora* sp.	+	−	−	−
9	*Chromaspirina inglisi*	−	+	−	+
10	*Comesa* sp.	−	+	−	−
11	*Comesoma* sp.	+	+	−	−
12	*Daptonema biggi*	+	+	−	−
13	*Daptonema hirsutum*	+	+	+	−
14	*Daptonema oxycerca*	−	+	+	−
15	*Daptonema procerum*	−	+	+	+
16	*Daptonema* sp.	+	+	+	−
17	*Daptonema tenuispiculum*	−	+	−	−
18	*Desmodora communis*	+	+	+	+
19	*Desmodora pontica*	−	−	+	−
20	*Desmodora scaldensis*	−	+	+	+
21	*Desmodora* sp.	+	−	+	+
22	*Desmodora sphaerica*	−	+	−	−
23	*Desmoscolex* sp.	−	−	−	+
24	*Dichromadora* sp.	−	−	+	+
25	*Dorylaimopsis punctata*	+	+	+	+
26	*Dorylaimopsis* sp.	+	+	+	+
27	*Eleutherolaimus minutus*	−	+	−	−
28	*Eleutherolaimus stenosoma*	−	+	−	+
29	*Eurystomina* sp.	−	−	−	+
30	*Halalaimus gracilis*	−	+	+	−
31	*Halalaimus longicaudatus*	−	+	−	+
32	*Hopperia* sp.	−	−	+	+
33	*Leptolaimoides* sp.	−	−	−	+
34	*Longicyatholaimus* sp.	−	−	−	+
35	*Marylynnia complexa*	−	+	+	−
36	*Mesacanthion* sp.	−	−	−	+
37	*Metachromadora vivipara*	−	+	−	+
38	*Metalinhomoeus* sp.	−	−	−	+
39	*Microlaimus* sp.	+	+	−	−
40	*Monhystera* sp.	−	−	+	−
41	*Monoposthia costata*	−	+	+	+

42	*Nemanema* sp.	−	+	−	−
43	*Neochromadora* sp.	−	−	+	−
44	*Oncholaimellus* sp.	−	+	+	−
45	*Oxystomina aesetosa*	−	+	+	+
46	*Oxystomina elongata*	−	+	+	−
47	*Oxystomina* sp.	−	+	−	−
48	*Paracomesoma dubium*	−	+	+	+
49	*Parasphaerolaimus* sp.	−	+	−	−
50	*Parodontophora* sp.	−	+	+	−
51	*Polygastrophora* sp.	−	+	+	−
52	*Pontonema* sp.	−	−	+	−
53	*Pselionema longiseta*	−	+	+	+
54	*Quadricoma scanica*	−	+	+	−
55	*Quadricoma* sp.	+	+	+	+
56	*Sabatieria alata*	−	−	+	−
57	*Sabatieria elongata*	−	+	−	−
58	*Sabatieria ornata*	−	+	−	+
59	*Sabatieria preadatrix*	+	+	+	+
60	*Sabatieria pulchra*	+	+	−	−
61	*Sabatieria punctata*	−	+	−	−
62	*Sabatieria* sp.	+	+	+	−
63	*Sphaerolaimus bulticus*	+	+	+	+
64	*Sphaerolaimus gracilis*	−	+	+	−
65	*Sphaerolaimus islandicus*	−	+	+	−
66	*Sphaerolaimus* sp.	−	+	+	−
67	*Spirinia parasitifera*	−	+	−	−
68	*Terschellingia communis*	−	+	+	+
69	*Terschellingia longicaudata*	+	+	+	+
70	*Terschellingia* sp.	−	+	−	−
71	*Theristus acer*	+	+	−	−
72	*Tricoma* sp.	+	+	−	+
73	*Trissonchulus* sp.	−	−	−	+
74	*Vasostoma* sp.	+	+	−	−
75	*Viscosia abyssorum*	−	+	+	+
76	*Viscosia cobbi*	−	−	+	−
77	*Viscosia glabra*	−	+	−	−
78	*Viscosia* sp.	−	−	−	+
79	*Viscosia viscosa*	−	+	+	+

A list of Abbreviations:

SES	Sundarban Estuarine System
BTA	Biological Trait Analyses
DO	Dissolved Oxygen
Chl *a*	Chlorophyll *a*
SPM	Suspended Particulate Matter
nMDS	non-metric multidimensional scaling
SIMPROF	Similarity Profile
SIMPER	Similarity of Percentage
PCA	Principal Component Analysis
CCA	Canonical Correspondence Analysis
ANOVA	Analysis Of Variance
PERMANOVA	Permutational Multivariate Analysis Of Variance

Certificate of Participation

This is to certify that **Moumita Ghosh,** Presidency University has participated and presented an oral entitled *"Structure of meiofaunal assemblages from sediments of different mangrove habitats at Sundarbans"* in the "**5th India Biodiversity Meet 2018 (International Conference)**", held at Indian Statistical Institute, Kolkata, from 15th -17th March, 2018.

Abhishek Mukherjee
Organising Secretary

Sabyasachi Bhattacharya
Head, AERU, ISI

5th INDIA BIODIVERSITY MEET 2018
International Conference
15 -17 MARCH, 2018

ICB 2019

International Conference on Benthos

Theme: Conserving Diversity and Productivity of Benthic Systems

Certificate

This is to certify that,

Prof. / Dr. / Mr. / Ms. MOUMITA GHOSH,

PRESIDENCY UNIVERSITY, KOLKATA

has attended the *International Conference on Benthos* (ICB 2019), organised by the Department of Marine Biology, Microbiology and Biochemistry, School of Marine Sciences, Cochin University of Science and Technology held from 6th to 8th March 2019 in Seminar complex, CUSAT, Kochi-22, Kerala, India.

He / She also presented a paper / ~~presented a poster~~ / ~~delivered a Invited talk~~ / ~~chaired a techincal session~~ titled VERTICAL DISTRIBUTION AND VARIABILITY OF MEIOBENTHIC ASSEMBLAGES FROM SUNDARBAN ESTUARINE SYSTEM, INDIA

We wish his / her the best for future endeavours.

Dr. Priyaja P.
Assistant Professor
Department of Marine Biology, Microbiology and Biochemistry
School of Marine Sciences, CUSAT
& Organising Secretary ICB 2019

DEPT. OF MARINE BIOLOGY, MICROBIOLOGY & BIOCHEMISTRY
UNIVERSITY OF SCIENCE & TECHNOLOGY
FINE ARTS AVENUE
ERNAKULAM
COCHIN-682 016

Dr. S. Bijoy Nandan
Professor and Head
Department of Marine Biology, Microbiology and Biochemistry
School of Marine Sciences, CUSAT
& Convener, ICB 2019

Kochi-22
8th March, 2019

ICB 2019, CUSAT, KOCHI, INDIA

Regional Studies in Marine Science 31 (2019) 100778

Contents lists available at ScienceDirect

Regional Studies in Marine Science

journal homepage: www.elsevier.com/locate/rsma

Does vertical distribution of meiobenthic community structure differ among various mangrove habitats of Sundarban Estuarine System?

Moumita Ghosh, Sumit Mandal *

Marine Ecology Laboratory, Department of Life Sciences, Presidency University, 86/1, College Street, Kolkata 700073, India

HIGHLIGHTS

- Vertical distribution of meiofauna was assessed from five mangrove vegetation of Indian Sundarbans.
- *Sonneratia caseolaris* harboured the highest density of meiofauna with the lowest in *Bruguiera gymnorrhiza*.
- Vertical profile of meiofaunal composition suggested upper 3–4 cm contained 90% of total fauna.
- The nematode fauna consisted of 52 species dominated by r-strategists.
- *Desmodora scaldensis* was the most dominated nematode species among all vegetation.

ARTICLE INFO

Article history:
Received 23 April 2019
Received in revised form 10 July 2019
Accepted 30 July 2019
Available online 1 August 2019

Keywords:
Mangrove
Sundarbans
Meiofauna
Vertical stratification
Nematode
Maturity index

ABSTRACT

Mangroves are the most productive environments that play significant ecological and socioeconomic roles. For the first time we investigated vertical stratification of meiofaunal community and nematode species composition from the sediments of five mangroves (*Aegiceras corniculatum*, *Bruguiera gymnorrhiza*, *Avicennia alba*, *Rhizophora mangle* and *Sonneratia caseolaris*) at Bali Island in the worlds' largest mangrove ecosystem of Sundarbans, India. Among different mangrove species, *S.caseolaris* had the highest density of meiofauna with the lowest in *B. gymnorrhiza*. A total of eight taxa were recorded from the sediment of different mangrove habitats. In terms of percentage composition, free-living nematodes dominated followed by harpacticoid copepods, kinorhynch, ostracods, foraminifera, polychaete, halacarid mite and bivalve juvenile. The vertical profile of meiofaunal composition suggested upper 3–4 cm harboured 90% of total meiofauna, although they were present up to 15 cm depth. Environmental variables explained meiofaunal community structure. Availability of food sources such as phaeopigments, Chlorophyll *a*, organic carbon and sediment texture controlled meiofaunal distribution. The nematode fauna consisted of 52 species belonging to 39 genera and 20 families. The trophic structure of nematode taxa revealed a community dominated by epistrate feeders (2A) followed by selective deposit feeders (1A). Moreover, marine nematode genera were used to test Maturity Index (MI), life strategy or biological traits (i.e. c–p classes) and Index of Trophic Diversity (ITD) for assessing ecological health. Higher MI among different mangrove vegetation indicated a stable environment; moreover, biological trait analysis showed that mangrove sediments were dominated by r-strategists. Lower values of ITD index revealed a proportionate occurrence of trophic diversity in nematode communities among different vegetation. In the current context of habitat destruction and anthropogenic perturbations, investigation of ecological interactions between mangroves and meiofauna would be imperative for ecosystem monitoring and sustainable development in future.

© 2019 Elsevier B.V. All rights reserved.

1. Introduction

Mangroves, the most implicit element of the world, are living at the confluence of land and ocean in the tropics and sub-tropical regions. They play an influential role in various ecosystem services like carbon sequestration, soil formation, hydrological cycle regulation, mitigation of coastal erosion and extreme weather events, such as storms, cyclones or tidal surges (Kathiresan and Bingham, 2001; Danielsen et al., 2005; Spalding and Collins, 2010). With a number of floristic species, the shallow water mangrove vegetation endowed with a plethora of commercially valuable living resources like fin and shell fishes and sustains the fisheries of entire eastern coast (Mandal et al., 2012). This ecosystem is biogeochemically important for sediment, carbon, nutrient, and contaminant accumulation also (Alongi, 2002).

The world's largest contiguous deltaic mangrove, popularly known as Sundarbans, is situated across India and Bangladesh

* Corresponding author.
E-mail address: sumit.dbs@presiuniv.ac.in (S. Mandal).

https://doi.org/10.1016/j.rsma.2019.100778
2352-4855/© 2019 Elsevier B.V. All rights reserved.

Thalassas: An International Journal of Marine Sciences
https://doi.org/10.1007/s41208-019-00129-3

Living with Nematode: an Epibiont *Trematosoma rotunda* Associated with Basibiont *Desmodora scaldensis* from Matla Estuary, Sundarbans, India

Moumita Ghosh[1] · **Sumit Mandal**[1]

Received: 16 October 2018 / Revised: 8 February 2019 /
© Springer Nature Switzerland AG 2019

Abstract
In the present study, we reported the symbiotic associations of suctorian epibionts *Trematosoma rotunda* (Allgén 1952) with marine nematode *Desmodora scaldensis* de Man 1889. The attachment of the epibionts on the cuticle of marine free-living nematodes was reported for the first time from subtidal zone of Matla estuary, Sundarbans, India. We compared the biometrics of epibiont *T. rotunda* with published literatures, discussed host-epibiont interactions and suggested future research opportunities.

Keywords *Desmodora scaldensis* · Epibionts · Free-living nematodes · Sundarbans · Symbiotic associations · *Trematosoma rotunda*

Introduction

Several benthic marine invertebrates like cnidarians, annelid worms, crustaceans, halacarid mites, molluscs are common hosts (basibionts) to some ciliates (epibionts) like peritrichids and suctorians (Arndt et al. 2005; Dias et al. 2010; Dovgal et al. 2008a; Fenchel 1987; Jankowski 1981). This extremely common phenomenon is known as epibiosis and has been reported across the world's ocean (Allgén 1955; Dovgal et al. 2009a; Fernandez-Leborans et al. 2012; Fisher 2003; Gelmboldt and Dovgal 2005). Epibionts are considered as the organisms growing attached to a living body often with facultative association in the sediment interstices (Wahl 1989). Epibiont ciliates are widespread in meiobenthic organisms (free-living nematodes, harpacticoid copepods, kinorhynchs, ostracods, oligocheates, tanaids) of marine environments (Chatterjee et al. 2014; Dovgal et al. 2008b; Padmakumar et al. 2014; Sergeeva and Dovgal 2014; Susetiono 2006). This kind of epibiotic settlement provides epibionts a hydrodynamically favourable position (Oswald and Seed 1986; Wahl 1989) and the flexible nature of the basibiont body surface reduces the danger of being dispersed with increased water turbulence (Riedl 1971). From Indian water, there are few publications about suctorian epibionts associated with meiofaunal basibionts (Ansari and Bhadury 2016; Bhattacharjee 2014; Chatterjee et al. 2013; Dovgal et al. 2008a, b; Ingole et al. 2010; Padmakumar et al. 2014; Panigrahi et al. 2015). In the present study, specimens of *Trematosoma rotunda* (Ciliophora, Suctorea) were reported as epibionts on the cuticle of free-living nematode *Desmodora scaldensis*, which belong to the family Desmodoridae from the Matla river of the Sundarban Estuarine System (SES). Though the suctorian ciliates *Trematosoma rotunda* (Allgén 1952) were reported on the cuticle of various nematode species, but the association with the nematode *Desmodora scaldensis* was recorded first time from subtidal zone of the Matla estuary, in the eastern Sundarbans, the world's largest mangrove ecosystem.

Materials and Methods

Study Site

As part of our ongoing biological study along the Matla estuary of the Sundarbans, meiofaunal organisms were collected and examined from eight stations across salinity gradient following standard protocols. Collection was made from northern part of the Matla estuary (latitude 21°59'11.30''N;

✉ Sumit Mandal
sumit.dbs@presiuniv.ac.in

[1] Marine Ecology Laboratory, Department of Life Sciences, Presidency University, 86/1, College Street, Kolkata 700073, India

Published online: 22 February 2019

Ecological Indicators 94 (2018) 139–150

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Original Articles

Impact of unusual monsoonal rainfall in structuring meiobenthic assemblages at Sundarban estuarine system, India

Moumita Ghosh[a], Sumit Mandal[a,*], Meenakshi Chatterjee[b]

[a] Marine Ecology Laboratory, Department of Life Sciences, Presidency University, 86/1, College Street, Kolkata 700 073, India
[b] Basanti Devi College, Kolkata 700029, India

ARTICLE INFO

Keywords:
Climate change
Estuarine system
Free-living nematodes
Meiobenthos
Monsoon
Organic carbon

ABSTRACT

The present study investigates the impact of monsoon on meiofaunal and free-living nematode communities of the Sundarban estuarine system (SES) both from taxonomic and functional point of view. In 2013, SES experienced an unusual rainfall event followed by cloud burst event at upper Himalayan regime. Average meiobenthic abundance declined considerably in the study area from early phase of monsoon (EM) (699 ± 1569.4 ind. 10 cm^{-2}) to later one (LM) (437 ± 949.9 ind. 10 cm^{-2}) probably due to high annual rainfall which completely flushed the estuary. Free-living marine nematodes were the dominant group among all other meiobenthic taxa in both phases of monsoon. Nematode community was made up of 49 genera in 22 families. Comesomatidae, Chromadoridae, Linhomoeidae and Xylidae were the richest and most abundant families. During both phases of monsoon, stations, which were represented by fine sediments and high amount of organic carbon, harbored higher meiofaunal densities and nematode diversity with a strong dominance of 1B and 2B trophic guilds of nematodes. Different feeding guilds of nematode would be able to reveal anthropogenic-induced stress, which could be useful in assessing ecological quality of estuarine ecosystems. The present study indicates that climate change mediated unusual monsoonal precipitation may notoriously affect the meiobenthic assemblages in tropical estuaries like SES. Thus, this study could be an important first stepping stone for monitoring the future environmental impact on meiobenthic community in the largest mangrove region of the world.

1. Introduction

Estuaries are considered as one of the most productive ecotone on earth (Prandle, 2009). It support invaluable ecological function and services in the context of its role in biogeochemical cycle, transport of nutrients, water purification, flux regulation of water, particles and pollutants, shoreline protection (Kennish, 2002; Alves et al., 2015). Due to its high biological productivity, estuaries forms the most important spawning zones and nursery ground for a wide variety of commercial fish and shell fish communities. Being a specialized dynamic environment, estuaries are usually well-marked by rapid variations in temperature, salinity, turbidity, dissolved oxygen and nutrient concentrations (Frontalini et al., 2014; Semprucci et al., 2014). These physico-chemical variables are characterized by riverine run-off during monsoon.

Benthic communities have been conventionally used as indicators of natural and man-made environmental perturbations (Borja et al., 2000; Vanaverbeke et al., 2011; Semprucci et al., 2015a). They are considered as sensitive to any kind of natural disturbances (tide, wave, currents etc.) because they could reflect an integrated response over time. In benthic realm, meiofauna contributes a considerable amount (10^5–10^6 individuals m^{-2}) in terms of total benthic biomass (Giere, 2009). They have been used as suitable yardstick of environmental health owing to their small size, high abundance and diversity, ubiquitous distribution, rapid generation times, fast metabolic rates, direct benthic development and sessile habitat (Kennedy and Jacoby, 1999; Schratzberger et al., 2000; Balsamo et al., 2012). They are important food source for large benthic organisms (McIntyre, 1977; Gerlach, 1978; Zeppilli et al., 2015) and help in recirculation of nutrients. It has been suggested that the production of meiofauna in estuaries and shallow water bodies is much higher than those of macrofauna (Balsamo et al., 2010). Among meiofauna, free-living nematodes and harpacticoid copepods are the richest animal groups (Boucher and Lambshead, 1995; Lambshead, 2004). On account of their dominance, ubiquitousness and robust bodies make these groups of organisms promising components to study natural and anthropogenic disturbances in marine ecosystem (Sanduli and De Nicola, 1991; Bongers and Ferris, 1999; Semprucci et al., 2015b). Thorough analyses of community structure can therefore provide a

* Corresponding author.
E-mail address: sumit.dbs@presiuniv.ac.in (S. Mandal).

https://doi.org/10.1016/j.ecolind.2018.06.067
Received 25 April 2018; Received in revised form 19 June 2018; Accepted 28 June 2018
1470-160X/ © 2018 Elsevier Ltd. All rights reserved.

Mar Biodiv (2018) 48:179–194
DOI 10.1007/s12526-016-0551-9

SENCKENBERG

CrossMark

ORIGINAL PAPER

Free-living marine nematode diversity from the Indian coasts

Moumita Ghosh[1] · **Sumit Mandal**[1]

Received: 6 May 2016 / Revised: 18 July 2016 / Accepted: 21 July 2016 / Published online: 9 August 2016
© Senckenberg Gesellschaft für Naturforschung and Springer-Verlag Berlin Heidelberg 2016

Abstract We present an updated taxonomic list of free-living nematode community from Indian coasts and Andaman & Nicobar Islands based on available published literatures. The Indian coast was divided into six basic habitats. The faunal list presents 288 nematode species, 227 genus, 44 families and 9 orders. The continental shelf had the highest species richness (225), followed by intertidal areas (81). The coastal diversity of nematofaunal community is higher in East than west sector. *Halalaimus*, *Viscosia*, *Sabatieria*, *Bathylaimus*, and *Theristus* are present in all regions. The fluctuation in species number throughout the Indian coast is probably due to differences in geomorphology, habitat heterogeneity among coastal regions, and unbalanced research efforts. Present paper may help to give more information on marine nematodes.

Keywords Free-living nematodes · Indian coasts · Andaman & Nicobar Islands · Faunal list

Introduction

Nematodes are better known as parasites, but the phylum consists of a diverse free-living fauna with ubiquitous distribution in sediment (Balsamo et al. 2010). The major free-living nematodes community colonize marine habitat where the specific distribution is so far in the range between 4,000–7,000 (Lorenzen 1994; Venekey et al. 2010; Appeltans et al. 2012). Free-living nematodes are small (30–500 μ) (SCOR Working Group 76 1994), inconspicuous numerically dominant metazoan meiobenthos (Lambshead and Schalk 2001). They occur under all climatic conditions from Antarctic pristine lakes (Ingole and Parulekar 1993) to the deepest parts of the Ocean (Lambshead et al. 2003). In coastal ecosystem, nematodes are important in the food web, as they have an intermediate trophic position (between bacteria/detritus/microalgae and macrofauna/megafauna) and as small crustaceans feed upon them (Gerlach and Schrage 1969), thus playing a crucial role in demersal fishery (Coull 1973; Schückel et al. 2013). Experimental evidence has shown that this group of organisms stimulates mineralization of organic matter (Findlay and Tenore 1982) and nutrient regeneration (Tietjen 1980) by grazing on bacteria. Due to their reduced mobility, short life cycle and higher reproductive ability, marine nematodes also play a significant role in biomonitoring studies (Platt and Warwick 1980; Semprucci et al. 2015b, 2016). Presently, the benthic environment has been affected by various pollutants due to different human activities. The abundance of nematode assemblages were significantly altered by sewage outfall and organic enrichment (Fraschetti et al. 2006), biodeposition of faeces during aquaculture (Mirto et al. 2002), hydrocarbon pollution (Mahmoudi et al. 2005), and trace element contamination (Boufahja et al. 2011). Nematodes can survive even in extreme conditions, while other benthic groups disappear (Heip 1980). Many researchers have highlighted that nematodes could adapt to extreme environments due to their behavioural or physiological modifications (Schratzberger et al. 2008; Armenteros et al. 2010; Balsamo et al. 2012; Semprucci et al. 2015a).

Though they are extremely abundant and their numbers exceed millions per square meter (Platt and Warwick 1980), their diversity and ecology remain poorly understood. A copious number of research papers have dealt with various

Communicated by M. Schratzberger

✉ Sumit Mandal
sumit.dbs@presiuniv.ac.in

[1] Marine Ecology Laboratory, Department of Life Sciences, Presidency University, 86/1, College Street, Kolkata, West Bengal, India

Sustain. Water Resour. Manag. (2018) 4:559–566
https://doi.org/10.1007/s40899-017-0139-y

ORIGINAL ARTICLE

Short-term variations in surface water properties in the Sundarban Estuarine System, India

Tanmoy Nandy[1] · Sumit Mandal[1] · Soumya Deb[1] · Moumita Ghosh[1] · Tirthankar Nath[2] · Meenakshi Chatterjee[2]

Received: 11 January 2017 / Accepted: 15 May 2017 / Published online: 20 May 2017
© Springer International Publishing Switzerland 2017

Abstract High resolution measurements were carried out to understand the short-term (<1 h) variability of surface water quality parameters in mangrove-dominated Sundarban Estuarine System of West Bengal, India during flood phases of spring-neap tidal cycle in a peak monsoon season August 2014. We observed that tidal propagation of both phases strongly influenced the water quality properties. During spring tide salinity, DO, pH, nitrate, phosphate, silicate, chlorophyll *a* and phaeopigments concentration exhibited increasing trends; whereas at neap tide nitrate, ammonia and chlorophyll *a* showed decreasing trends. Average nutrient concentrations were much higher during neap tide than spring tide. All the measured water quality parameters varied in every 15-min interval influenced by the tidal current, mangrove litter fall, re-suspension of bottom sediment and river runoff. The effect of tidal amplitude was observed to be the important factor in determining the variability in most of the water quality parameters.

Keywords Sundarban Estuarine System · Water quality · Monsoon · Spring–Neap Tide

✉ Sumit Mandal
sumit.dbs@presiuniv.ac.in

[1] Marine Ecology Laboratory, Department of Life Sciences, Presidency University, 86/1, College Street, Kolkata 700 073, India

[2] Basanti Devi College, Kolkata 700029, India

Introduction

Estuaries play an important role in biogeochemical cycle because of their capability to regulate a huge amount of river-borne major and minor elements entering the coastal environment. Estuarine ecosystems are complex, dynamic and experience strong gradients in water quality properties and complex hydrodynamic processes (Mitra et al. 2011). The distribution of nutrients and other environmental parameters in estuarine waters plays pivotal role in controlling biogeochemistry of estuaries. The Sundarban Estuarine System (SES) is a unique ecosystem, covered by mangrove vegetation which is very much tidally induced and all parts of the SES are propagated by the dominated semi-diurnal tide with an overall northward amplification (Chatterjee et al. 2013). Different physico-chemical parameters such as salinity, pH, dissolved oxygen (DO), chlorophyll and some essential micro-nutrients (N, P, S) are very much significant in controlling the productivity of estuarine system (Manasrah et al. 2006; Nixon et al. 1986). This mangrove-dominated estuarine region also provides major pathways for nutrient recycling and acts as a natural filter for pollutants coming from the human settlements and industrial area in its northern part. Measurements at hourly intervals or time series study are more common practice to study the changes in properties with diurnal and/or tidal variability, but sub-hourly changes of such environmental parameters have not been done earlier from this region, though Anand et al. (2014) had been reported variations in sub-hourly biogeochemical properties from Zuari estuary, central western part of India. The sub-hourly sampling strategy in an estuarine system is very essential to understand the intra-tidal variability of nutrients and the effect of tidal straining and suspended sediment on water column stratification (Uncles 2002). Cassidy and Jordan (2011)

Mar Biodiv (2016) 46:421–431
DOI 10.1007/s12526-015-0383-z

SENCKENBERG CrossMark

ORIGINAL PAPER

Modern benthic foraminiferal assemblages from the world's largest deltaic mangrove ecosystem, the Sundarbans

Areen Sen[1] · Moumita Ghosh[1,2] · Pradnya Khanderao[1] · Sunit Kumar Das[3] · Debmalya Roy Chowdhury[3] · Pankaj Kumar Sarkar[3] · Ratul Saha[3] · Punyasloke Bhadury[1]

Received: 29 September 2014 / Revised: 16 July 2015 / Accepted: 11 August 2015 / Published online: 4 September 2015
© Senckenberg Gesellschaft für Naturforschung and Springer-Verlag Berlin Heidelberg 2015

Abstract The Sundarbans is the world's largest contiguous mangrove ecosystem. Recent changes in the region have been reported due to a rise in relative sea level along with increased salinity intrusion. Intertidal benthic foraminifera are widely used as indicators of relative sea level change. The taxonomic diversity of foraminifera in the Sundarbans remains relatively understudied due to the remoteness of this ecoregion. The present study documented modern intertidal benthic foraminiferal assemblages across eight sites from previously unexplored eastern parts of the Indian Sundarbans. We also analyzed sediment texture from the study sites, which is essential for sea level reconstructions. Our study recorded an assemblage dominated by agglutinated genera that are characteristic of mangroves globally. However, we also recorded calcareous genera characteristic of higher-salinity zones, indicating saline intrusion further upstream in the region. In total, we recorded 15 species, representing ten different foraminiferal families. Total organic carbon (TOC) content and sediment composition showed variation across the studied sites. Canonical correspondence analysis (CCA) of the biological and environmental data confirmed its usefulness for understanding shifts in hydrological conditions across this region.

Communicated by P. Martinez Arbizu

✉ Punyasloke Bhadury
pbhadury@iiserkol.ac.in

[1] Integrative Taxonomy and Microbial Ecology Research Group, Department of Biological Sciences, Indian Institute of Science Education and Research Kolkata, Mohanpur, Nadia, West Bengal, India

[2] Present address: Presidency University, Kolkata, West Bengal, India

[3] WWF-India Sundarbans Program, Kolkata, West Bengal, India

Keywords Benthic foraminifera · Indian Sundarbans · Mangrove · Sediment texture · Total organic carbon (TOC) · Sea level · Canonical correspondence analysis (CCA)

Introduction

Mangrove ecosystems represent marginal marine habitats dominated by salt-tolerant halophytic angiosperms (Murray 2006). Globally, mangroves are restricted to the tropical zones between 32°N and 38°S. The Sundarbans deltaic mangrove is the world's largest contiguous area of mangrove habitat (Kumar and Mukherjee 2012). Since 1987, it has been designated a United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage Site, and is the world's only mangrove tiger habitat (Manna et al. 2010). The Sundarbans is located in the southernmost part of the Ganges-Brahmaputra-Meghna (GBM) riverine delta. The delta, which was formed by late Holocene deposits of the GBM river system, is spread across coastal parts of India and Bangladesh (Stanley and Hait 2000). The Indian Sundarbans has an area of 9630 km^2, of which 4267 km^2 is forested (Dey et al. 2012). Seven rivers flow through the Indian Sundarbans. Two of these (Hooghly and Mooriganga), located in the western part, receive freshwater input, while five (Saptamukhi, Thakuran, Matla, Gosaba and Haribhanga), located in eastern part, are tide-fed from the Bay of Bengal (Mitra et al. 2009). The Sundarbans ecoregion is faced with the constant threat of cyclones, storm surges, sea level rise, and reduced flow of freshwater into the mangrove system. In addition, in recent times, tilting of the delta towards the east and the rising seawater along with increased anthropogenic activities have altered the balance between freshwater and saline water in this ecosystem (Allison 1998; Stanley and Hait 2000). Given the precarious

ISBN : 978-93-84241-88-9

Marine Harpacticoid Copepod from Indian Coasts: a Review

Abir Lal Biswas[1], Moumita Ghosh[1] and Sumit Mandal[1*]
[1]Marine Ecology Laboratory, Department of Life Sciences, Presidency University, 86/1, College Street, Kolkata- 700 073, West Bengal, India.
* Corresponding author: sumit.dbs@presiuniv.ac.in

Abstract

We present an updated taxonomic list of marine harpacticoid copepod community from Indian water of 13 habitats including Andaman-Nicobar Island and Lakshadweep based on available published literature. The faunal list comprises 287 species, 132 genus and 32 families. Andaman & Nicobar Island has highest species abundance (129), followed by Eastern Intertidal (80). The diversity of harpacticoida is richer in eastern sector than western sector of India. The fluctuation in species number throughout the Indian coast is probably due to differences in geomorphology, habitat heterogeneity among coastal regions, difference of food source and unbalanced research efforts. Present paper may help to give more information on marine harpacticoid copepod from Indian coasts.

Key words: Harpacticoid copepods, Indian coasts, Andaman & Nicobar Island, Lakshadweep Island, habitat heterogeneity.

Introduction

Harpacticoid copepod belongs to the suborder Copepoda, class Maxillopoda, subclass Crustacea and phylum Arthropoda. They are permanent member of meiofauna which always remain within the meiofaunal size range 63-500 μm (Gray and Elliott, 2009). They are highly mobile crustaceans (Hicks and Coull, 1983) which exhibits second most abundant meiofaunal group in marine sediment, while the free-living marine nematodes are most dominant. Harpacticoid copepods are completely flexible and well suited for shifts in their food preferences during different developmental stages and also between different seasonal and tidal changes, which makes it easier for them to be mass cultured and used as different experimental models for pollution monitoring and aquaculture (Sun and Fleeger, 1995; McLachlan and Brown, 2006). Moreover, harpacticoids are more sensitive, responsive and compulsive to pollutants than nematodes, which in turn make them excellent indicators of pollution (Coull and Chandler, 1992; McLachlan and Brown, 2006).However, there are many controversies around the Nematode-Copepod ratio and also subject to criticism. Reducing very complex and labyrinth meiofaunal community into a single and simple ratio is